LAMONT GEOLOGICAL OBSERVATORY
(Columbia University)
Palisades, New York

1957 SOUND TRANSMISSION STATIONS

by

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ILLUSTRATIONS

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I. INTRODUCTION

During the summer of 1957, as part of Lamont Geological Observatory's continuing program of underwater sound transmission studies, thirty-one sound transmission runs were made in conjunction with seismic refraction profiles, using explosives as the sound source. All the sound runs were made using a near-surface hydrophone and sound sources. Eleven of the sound runs were made between Recife, Brazil, and Trinidad, and the other twenty were made in the eastern Caribbean between Trinidad and Cuba. The sound runs were made under conditions of widely differing water depth, water structure, bottom topography, geology, and geographic position. The location and length of the transmission runs were determined by the seismic stations. There are examples of up slope, down slope, shallow water, mid-depth water and deep water transmission.

The transmission data are presented as the relative total energy of all arrivals corrected for cylindrical spreading as a function of range in octave bands from 37.5 cps to 4800 cps. The data were not reduced to absolute spectrum levels since the voltmeter used to calibrate the recording system was not functioning properly.

At the time each transmission run was made, as many of the environmental parameters as possible were measured.

II. OBSERVATIONS AT SEA

The transmission runs were conducted with M. V. THETA as the receiving ship. R. V. VEMA was the shooting ship for the transmission runs between Recife and Trinidad, and A. R. A. BAHIA BLANCA of the Argentine Navy was the shooting ship between Trinidad and Cuba. The shooting ship fired explosive charges of 2.5 lbs. of tetrytol (M-1 demolition blocks equivalent to 3 lbs. of TNT) with burning fuse at a depth of approximately 50 ft. The transmission shots were fired between the shots for the seismic refraction profile, so in some instances their spacing was erratic.

The range of the sound transmission shots was taken from navigation plots (distance versus time of day) derived from the water wave travel times of the refraction data. The range accuracy using this method is estimated to be 100 yards.

The recording system was similar to that reported by Tirey, Ewing, and Nafe (1958). The acoustic data were recorded on a two-channel magnetic tape recorder, Magnecorder Type PT6-BN, from an AX-58c Brush hydrophone through a 40-db postamplifier. The hydrophone was also used for the seismic measurements and had to be slacked in certain instances to reduce the low-frequency background noise. Consequently the hydrophone depth was variable and uncertain

for each shot, but from similar observations using a depth meter the depth probably varied between 40 and 125 feet.

Bathythermograph observations and a seismic refraction station were made at the time of each sound transmission run.

III. DATA ANALYSIS

The magnetic tapes were analyzed with equipment similar to that used in the past by several other laboratories and was described by Officer and Dietz (1953). The signal was passed through a variable bandpass filter and divided. Part of the signal was passed through a Philbrick energy computer and was recorded on one channel of a two-channel Sanborn pen recorder as a function of the integrated square of the input voltage. The other part of the signal was recorded on the second channel as the logarithm of the rectified input voltage. Since the response time of the logarithmic channel was too long to record the sharp peaks of the signals, this trace was used only to identify the various arrivals and not to measure peak pressures.

IV. THE DATA

Figure 1 shows the location of the sound runs. Each sound transmission run with its accompanying environmental data will be referred to as a station. The omission of station numbers was the result of incomplete data or hydrophone trouble.

Figures 2 through 32 present a composite picture of the transmission losses corrected for cylindrical spreading and measurements of some of the environmental parameters that are a major influence in determining the transmission anomaly. The loss curves are separated for clarity and their spacing does not represent the relative energies of the different frequency bands.

The bathythermograph data were only plotted to a depth of 400 ft. which is sufficient to show the major break in the thermocline. The bathythermograph profiles are shown at the approximate location where they were taken along the shooting track.

Part of the seismic data shown directly below the bottom topography (Stations 24 through 35) has been worked up in detail and will be reported in one of the geophysical publications in the near future. The final interpretation of the seismic data for Stations 1 through 23 has not been completed, so the geological sections are shown as straight lines. Some of the profiles have large topographic changes which make them difficult to interpret.

The topography for the refraction profile is an average of the topography of both ships shooting the reversed seismic station, while the topography for the sound run is that traversed only by the vessel firing the sound propagation shots. Thus, in some cases the two topographic profiles are different.

Figures 33 through 35 present a comparison of the loss curves in the 300-600 cps octave bands beyond a range of 10 kyds. The curves are grouped into figures by water depth. The curves of each figure are further subdivided by geographic location.

V. DISCUSSION OF DATA AND CONCLUSIONS

Since the sound transmission stations were conducted under widely differing environmental conditions, the stations are grouped and discussed primarily by water depth rather than one of the other parameters such as geographic location, water structure, bottom topography, or bottom sediment velocity. The division of the stations by water depth was made arbitrarily in the following way: less than 300 fathoms, shallow water; 300 to 1500 fathoms, mid-depth water; and deeper than 1500 fathoms, deep water.

a. Shallow Water Stations

Stations No. 1, 6, 7 and 13 were conducted in water depth less than 150 fathoms. It is difficult to speculate on the mechanisms or combinations of mechanisms that were responsible for determining each particular curve. There are too few stations to attempt an analysis on a statistical basis similar to the method used by Baxter (1957). For comparison of the losses at the different stations, the 300-600 cps energy losses for the shallow stations are shown in Figure 33. The propagation losses were less for Station No. 6, which had smoother bottom topography and deeper water than the other stations. Although

Stations No. 1 and 7 were in about the same depth of water, the loss at Station No. 7 was 0.9 db/kyd versus 0.6 db/kyd for Station No. 1. Two striking differences in the environmental data were the absence of a sound channel at Station No. 7 and the large difference in upper sediment velocity at the two stations. The transmission anomaly for Station No. 13 was much greater than for the other shallow stations, 1.4 and 3 db/kyd. The greater losses resulted from the shallow surface channel, rough bottom topography, and sloping bottom.

In general for the shallow stations, the low-frequency anomalies were larger than the high-frequency anomalies (Stations 1, 13, 6A and 7A). If the low-frequency losses were large, the high-frequency losses were also high as noted by Hersey, et al (1956) for sound propagation along the east coast of the United States in shallow water.

b. Mid-Depth Water Stations

The fifteen stations classed as mid-depth were distributed widely geographically and physiographically. In this group there are examples of up-slope, down-slope, smooth bottom topography, and across-ridge transmission. Of the fifteen stations only four were made along topography with changes less than 200 fathoms.

Figure 34 shows the 300-600 cps octave band loss curves grouped by geographical location for comparison. The curves were started at the same level at a range of 10 kyds since the data are relative energies, but the energy levels at this range would certainly be different for the various curves. Topography and water depth were major factors in determining

the transmission anomalies. The loss curves over the smoother topography (Stations No. 3, 4, and 11) in general are smoother and have a smaller slope than for the other stations. The loss for Station No. 11 was about 0.1 db/kyd compared with 2.0 db/kyd for Station No. 23 which was over steep down-slope, rough topography.

The up-slope transmission appeared to be better than the down-slope transmission. This probably resulted from water depth as the down-slope stations were in shallower water which would give more bottom reflections for the distance traveled.

Stations No. 16A and 17 show an increase in energy with range from 10 to 50 kyds. At both stations there was an absence of a strong surface sound channel, and the sound was refracted down near the source making the transmission paths bottom-reflected. At short ranges the angles of incidence were less than critical and loss of energy by refraction into the bottom was large. As the angles increased beyond critical, there was near total reflection. Some of the increase in energy may have resultedfrom RSR paths described by Ewing and Worzel (1948), but a more likely explanation is that this was the interval of best reception via bottom-reflected paths which occurs between the critical angle and the limiting ray as discussed by Officer (1958).

Station No. 8 was of special interest because of the points which fall 4 to 18 db below loss curves. The points of low energy were the result of the hydrophone depth which was variable for all of these tests.

All the octave bands were affected with the minimum effect being on the two lower bands. The largest variations were in the 600-1200 cps band.

For Stations No. 23, 24, and 26 in the frequency range below 300 cps, the signals were of such low amplitude they could not be integrated from the background noise beyond a range of about 30 kyds. This appears to be primarily a topographic effect. At Station No. 23, the propagation was down a steep slope from 100 to 900 fathoms. Station No. 26 propagation was down a steep slope and across a ridge. Station No. 24 propagation was down a slope and across a ridge.

The low-frequency losses were less than the high frequency losses at all of these stations, with the exception of Stations No. 12, 23, 24, and 26. In general, if the low-frequency losses were great, the high-frequency losses were large, too.

c. Deep Water Stations

All the deep water stations were made over rough bottom topography with the exception of Station No. 9 in the Guiana Basin. The sound transmission losses in deep water were less than for mid-depth and shallow water. One of the major factors for the lower losses in deep water was the smaller number of bottom reflections to cover the same range. The low frequencies were propagated better than the high frequencies as was the case for mid-depth stations.

Using the 300-600 cps band for comparison (Fig. 35), the losses in excess of cylindrical spreading for the various stations had a range from 0.07 db/kyd at Station No. 9 to 0.34 db/kyd at Station No. 10,

where the bottom was up-slope. The average anomaly for all the deep stations was about 0.15 db/kyd.

At Station No. 19 there was evidence of focusing at a range of 62 kyds, which may be the result of RSR paths, but with the high surface sound velocity and a depth of only 2000 fathoms, it does not appear possible for these paths to have existed. A more probable explanation would be focusing relating to the rough bottom topography. Station No. 35 shows energy increasing with range, but, as discussed for mid-depth Stations No. 16A and 17, this probably resulted from improved reflection angle.

The stations with the lower loss rates in this group compare well with the four transmission runs between Bermuda and the Mid-Atlantic Ridge reported by Tirey, Ewing, and Nafe (1958).

The sound transmission at all the stations was by surface-bottom reflection and surface sound channel. The propagation anomalies for this type of transmission would be strongly influenced by water depth, water structure, bottom topography, and bottom sediments. The sound runs show the first three factors were major influences in determining the anomalies, but no definite correlation could be made with the seismic data. There is no doubt that the bottom sediments play a role in determining the losses for bottom-reflected transmission. The poor correlation of the sound and seismic data probably results from the rough bottom topography at these stations being such a prominent factor that it obscures

the effects of the bottom sediments.

A new method of measuring the thickness of the upper sediments by a reflection profiling technique recently developed at Lamont should be useful in showing the effect of the bottom sediments on the transmission anomalies (Ewing and Tirey, 1961).

VI. SUMMARY

High-frequency losses were less than low-frequency losses in shallow water.

Low-frequency losses were less than high-frequency losses in mid-depth and deep water.

Transmission losses were principally a function of bottom topography and water depth.

If losses at one frequency were large, the losses at all the frequencies tended to be large.

The results given here were obtained as part of a program to gather sound transmission data in various parts of the oceans, which may be of present or future interest to the Navy. The data of principal value are the shapes of the transmission loss curves which show expectable propagation conditions for the various frequency bands studied.

Acknowledgments

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It is with pleasure that we acknowledge the assistance of the officers and men of A. R. A. BAHIA BLANCA of the Argentine Navy who fired most of the charges.

John Hennion, John Nafe and John Antoine made important contributions to this work, both in the field measurements and in analysis.

Clyde Buchanan, Betty Batchelder and Paul Kunsman assisted in the sound data reduction and in the drafting of the figures.

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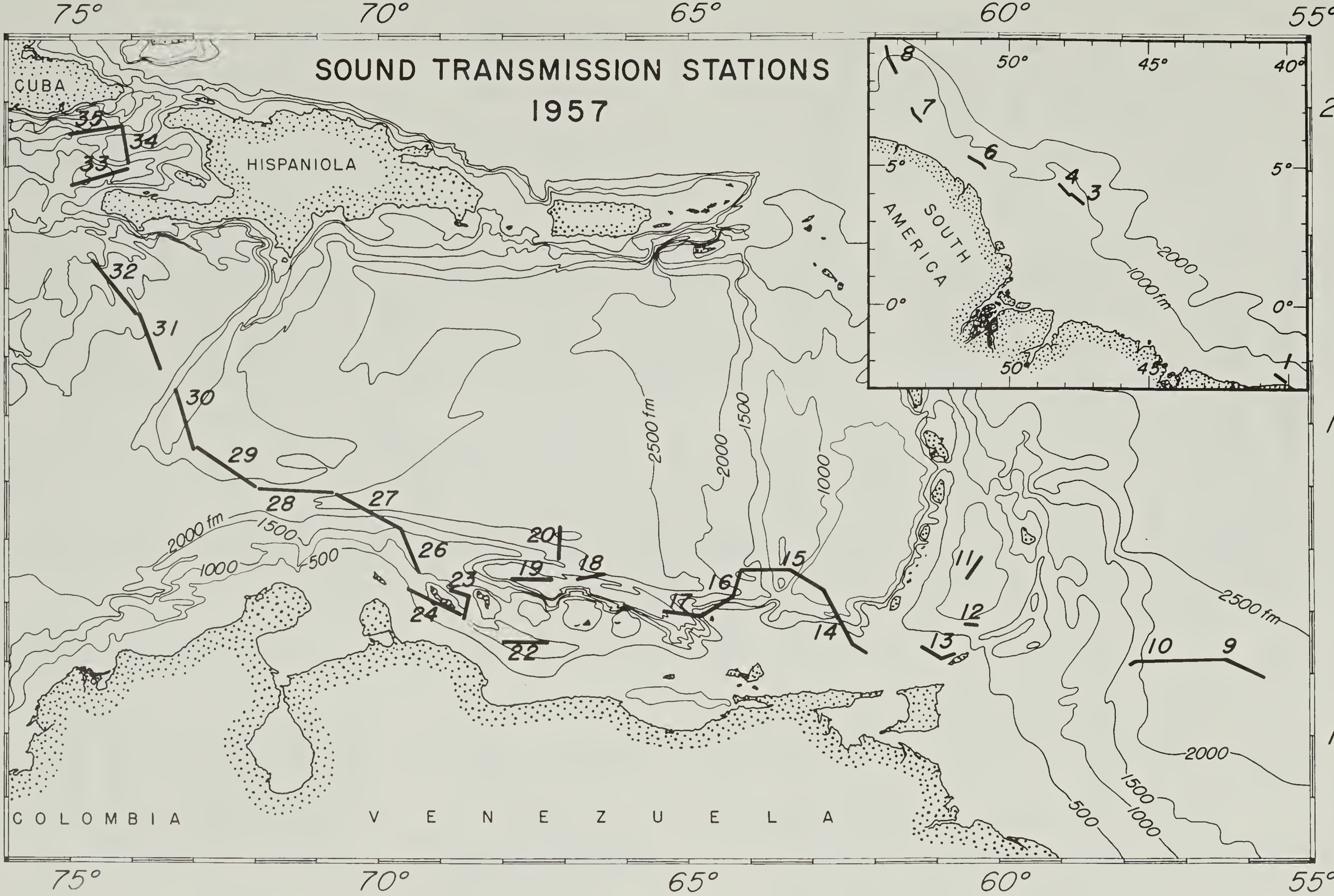
SOUND TRANSMISSION STATIONS
1957
CUBA
HISPANIOLA
SOUTH AMERICA
COLOMBIA
V E N E Z U E L A
75°
70°
65°
60°
55°
20°
15°
10°
50°
45°
40°
5°
0°
2500 fm
2000
1500
1000
500
2000 fm
1000 fm
1
3
4
6
7
8
9
10
11
12
13
14
15
16
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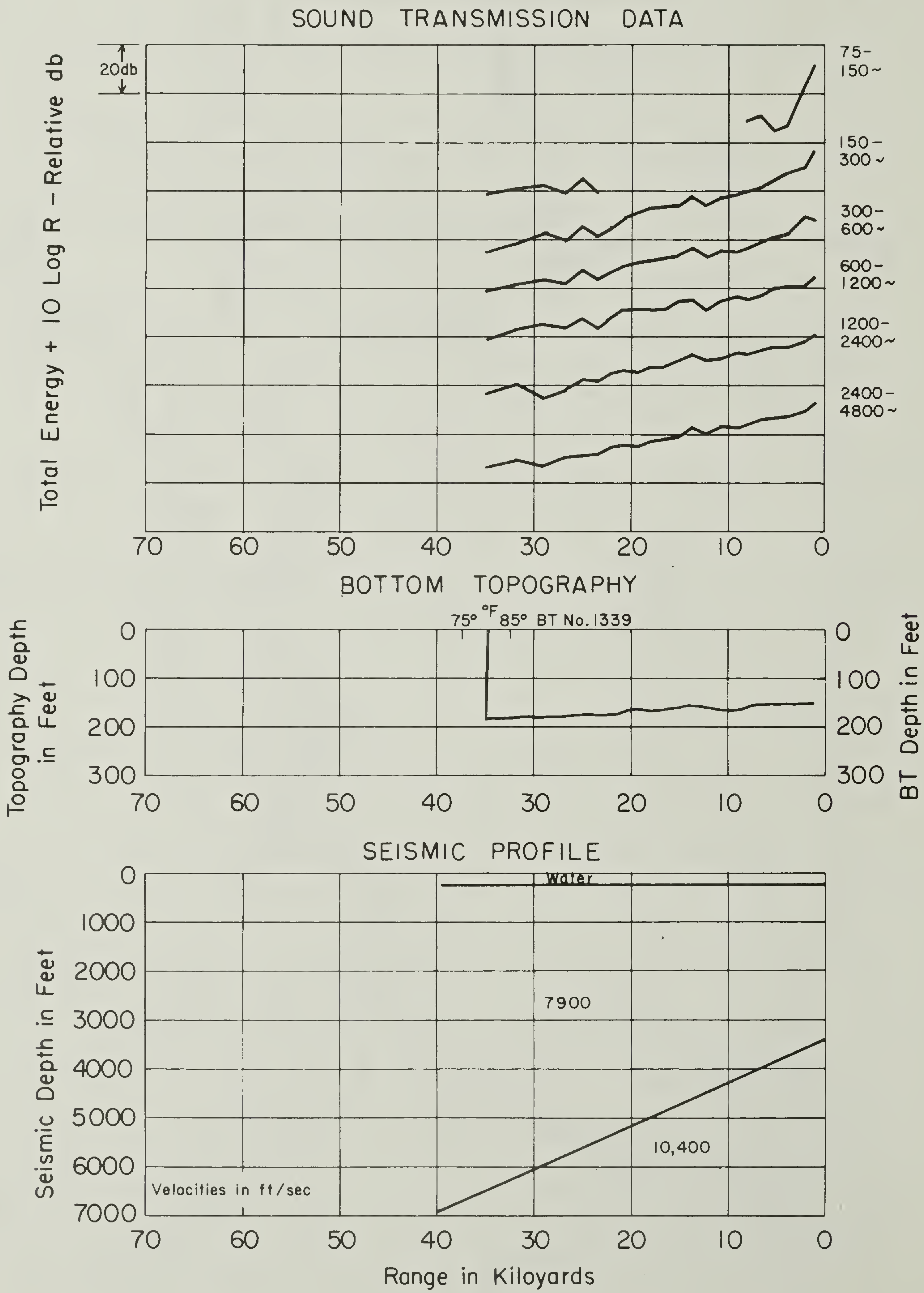
33
34
35

STATION NO. 1



SOUND TRANSMISSION DATA
Total Energy + 10 Log R – Relative db
20db
75–150~
150–300~
300–600~
600–1200~
1200–2400~
2400–4800~
70 60 50 40 30 20 10 0
BOTTOM TOPOGRAPHY
Topography Depth in Feet
BT Depth in Feet
75° °F 85° BT No. 1339
0 100 200 300
70 60 50 40 30 20 10 0
SEISMIC PROFILE
Seismic Depth in Feet
0 1000 2000 3000 4000 5000 6000 7000
Water
7900
10,400
Velocities in ft/sec
70 60 50 40 30 20 10 0
Range in Kiloyards

STATION NO. 3

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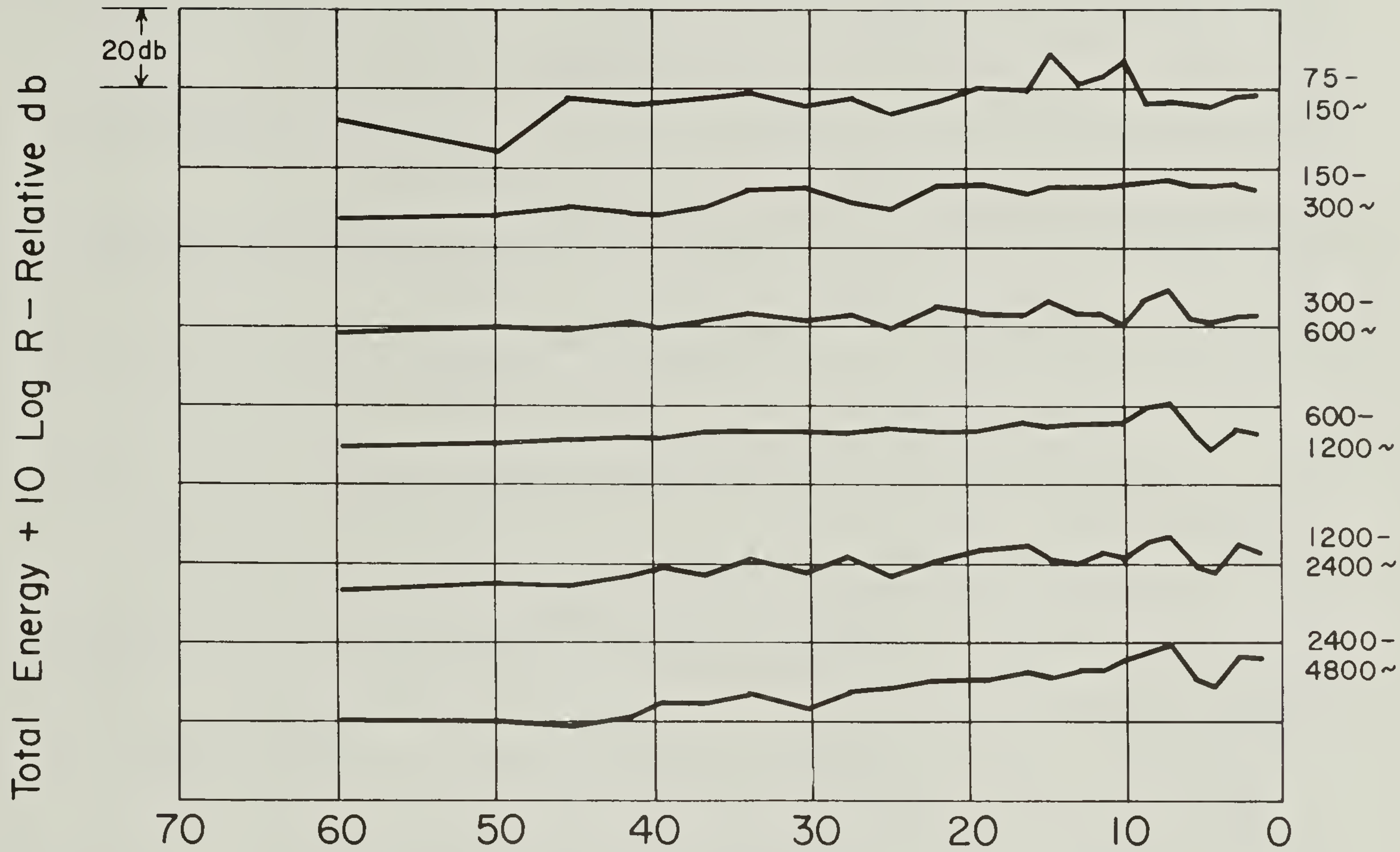

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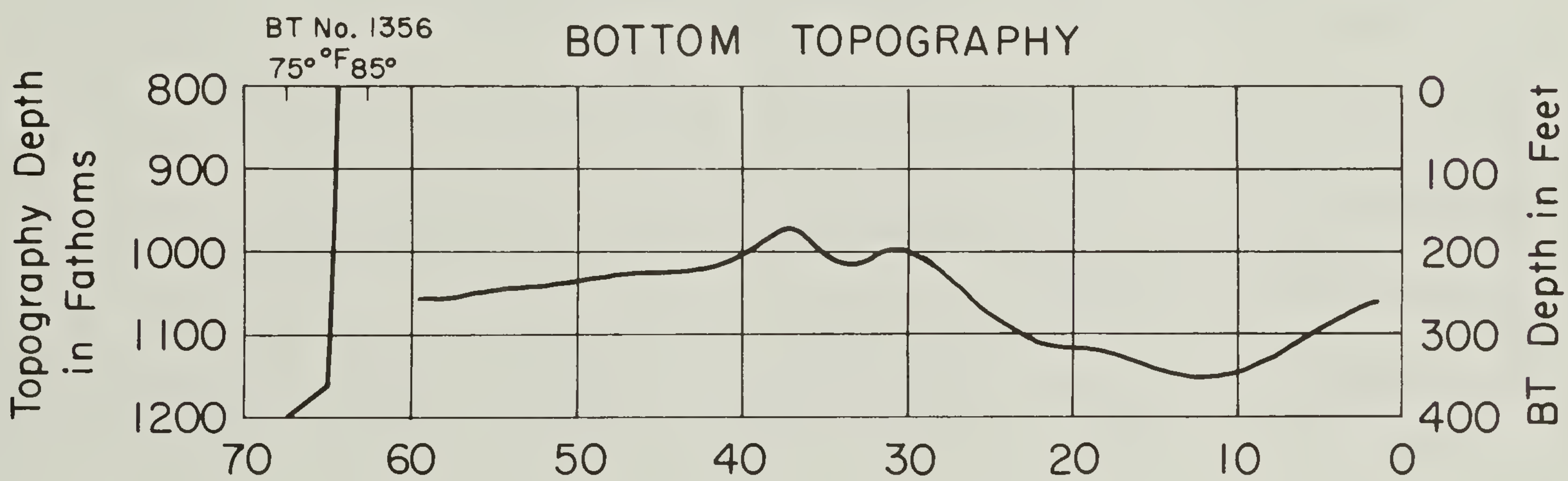

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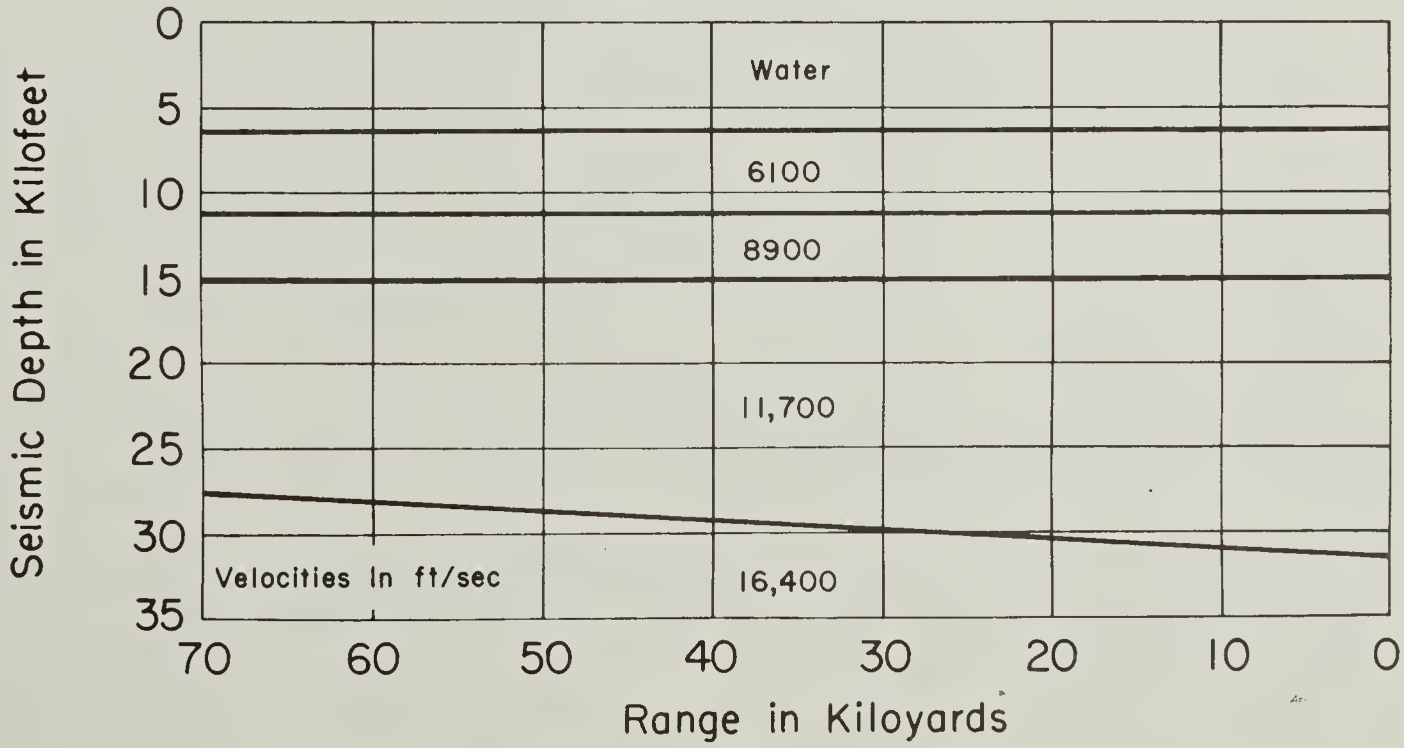

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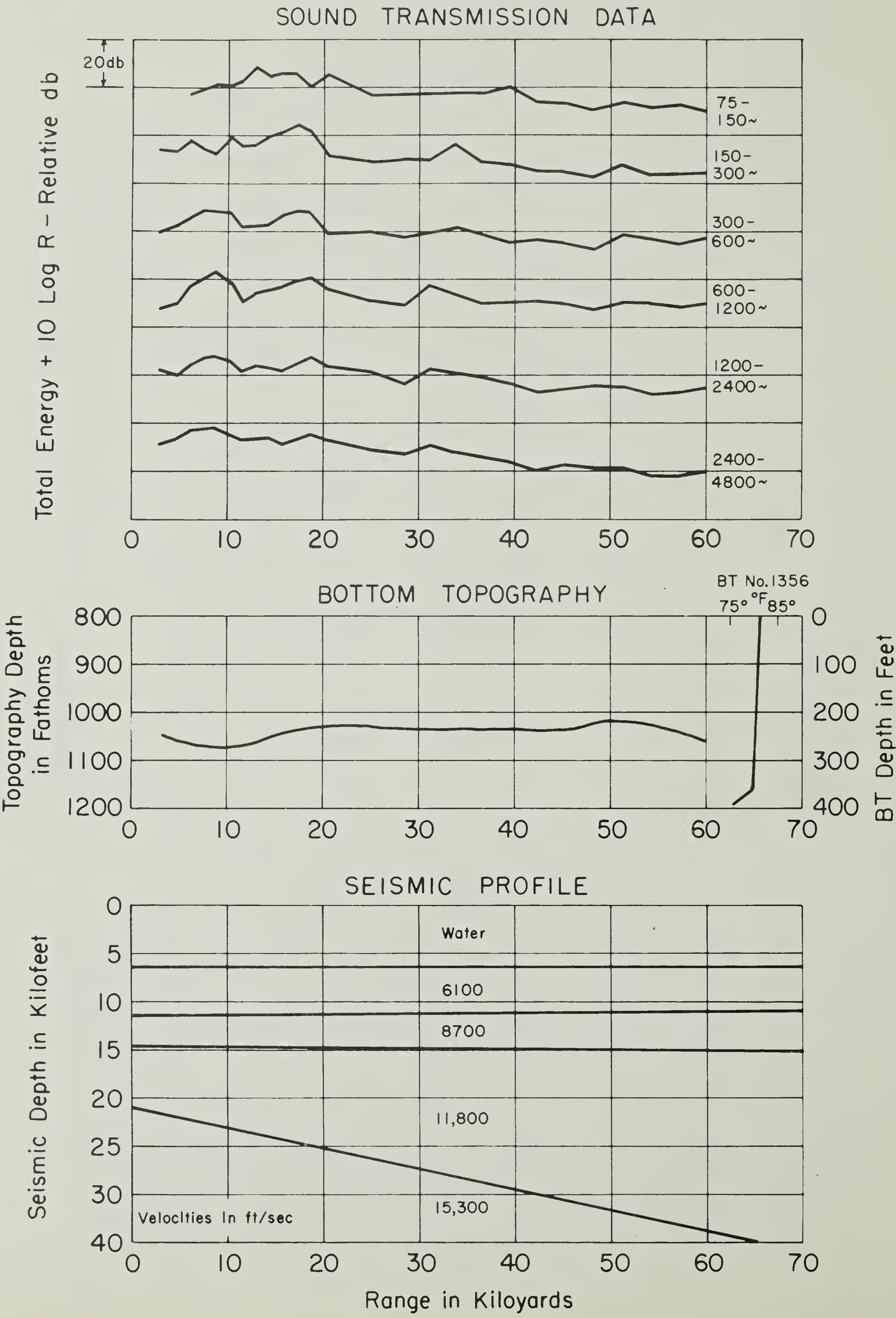
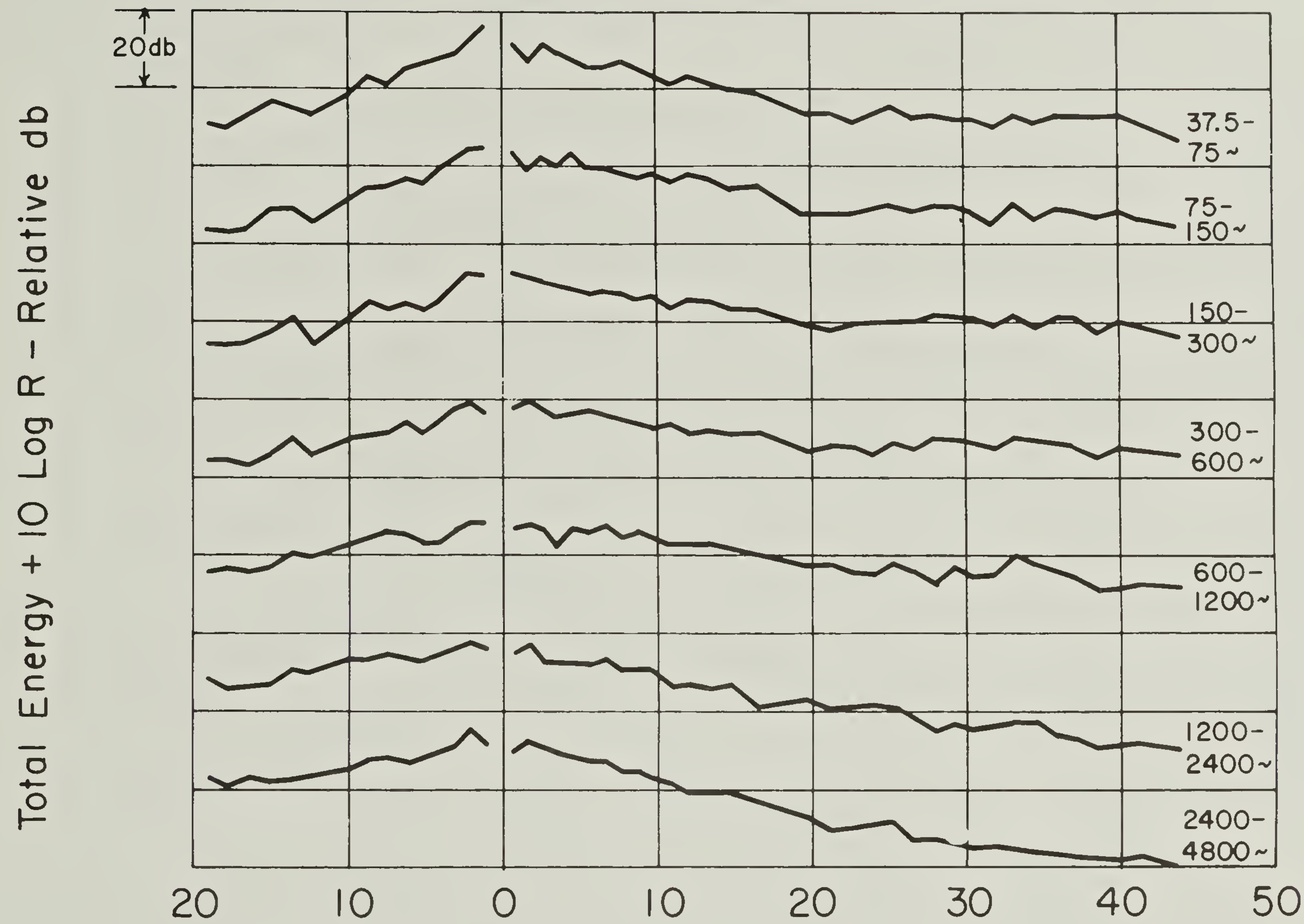

SOUND TRANSMISSION DATA
20db
Total Energy + 10 Log R – Relative db
75-
150~
150-
300~
300-
600~
600-
1200~
1200-
2400~
2400-
4800~
0
10
20
30
40
50
60
70
BOTTOM TOPOGRAPHY
BT No. 1356
75°
°F
85°
Topography Depth in Fathoms
800
900
1000
1100
1200
BT Depth in Feet
0
100
200
300
400
SEISMIC PROFILE
Seismic Depth in Kilofeet
0
5
10
15
20
25
30
40
Water
6100
8700
11,800
15,300
Velocities in ft/sec
Range in Kiloyards

STATION NO. 6

SOUND TRANSMISSION DATA



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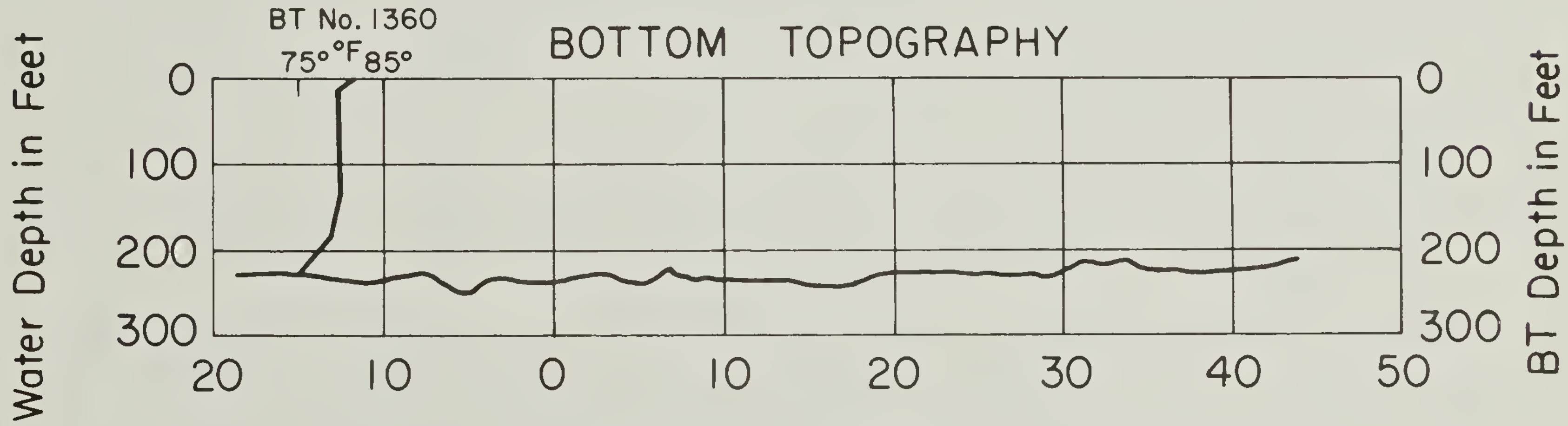

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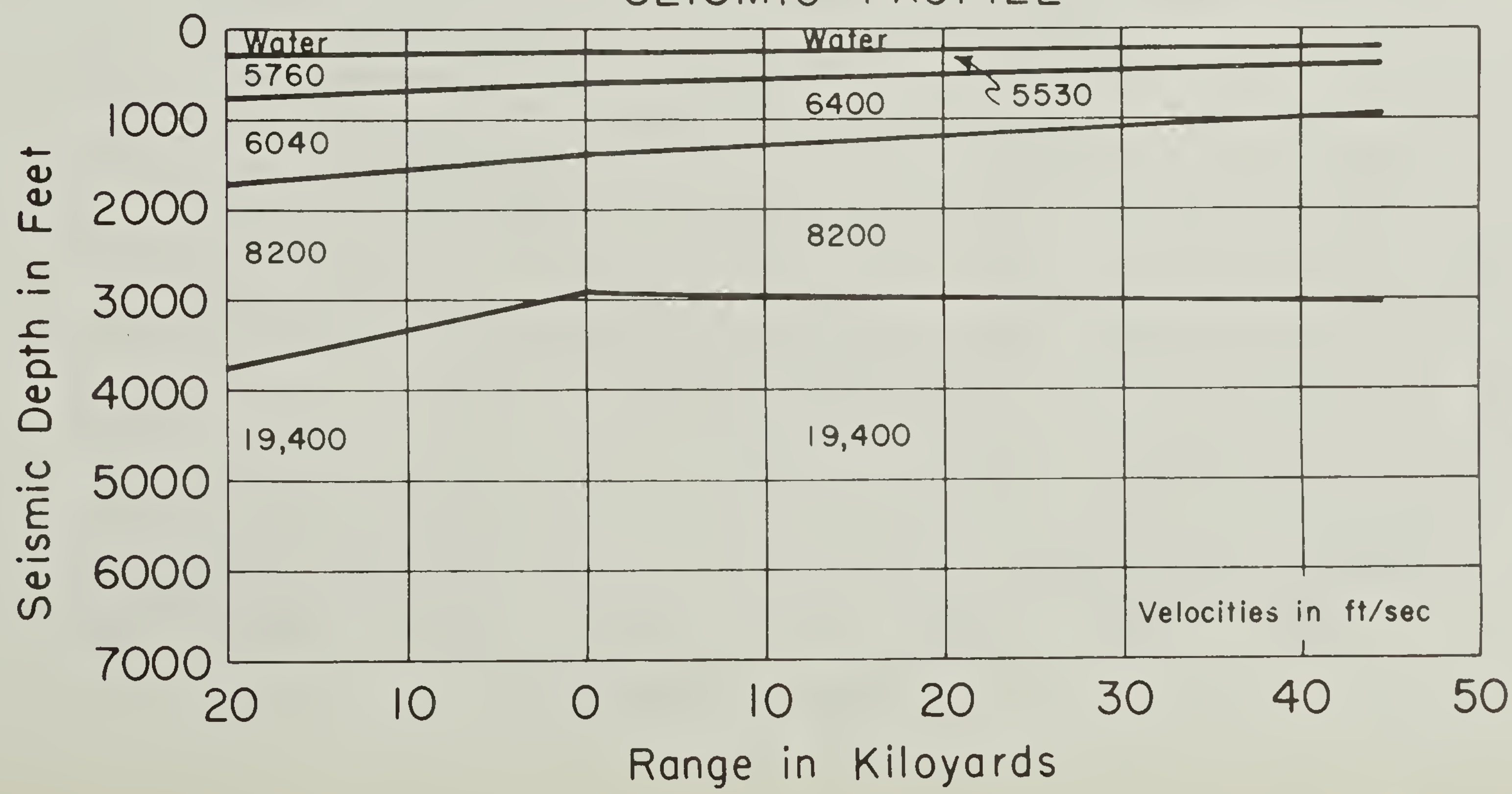

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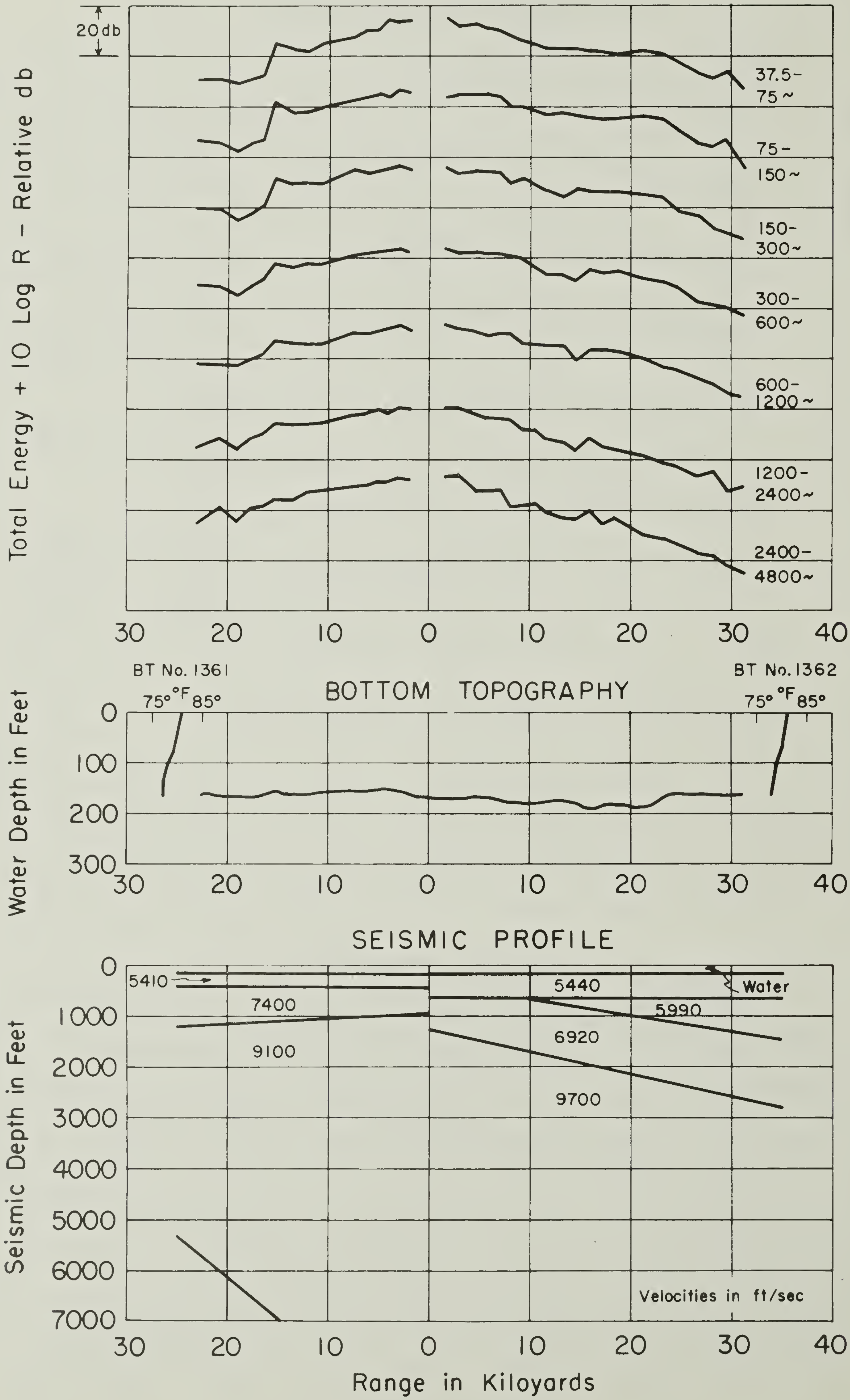

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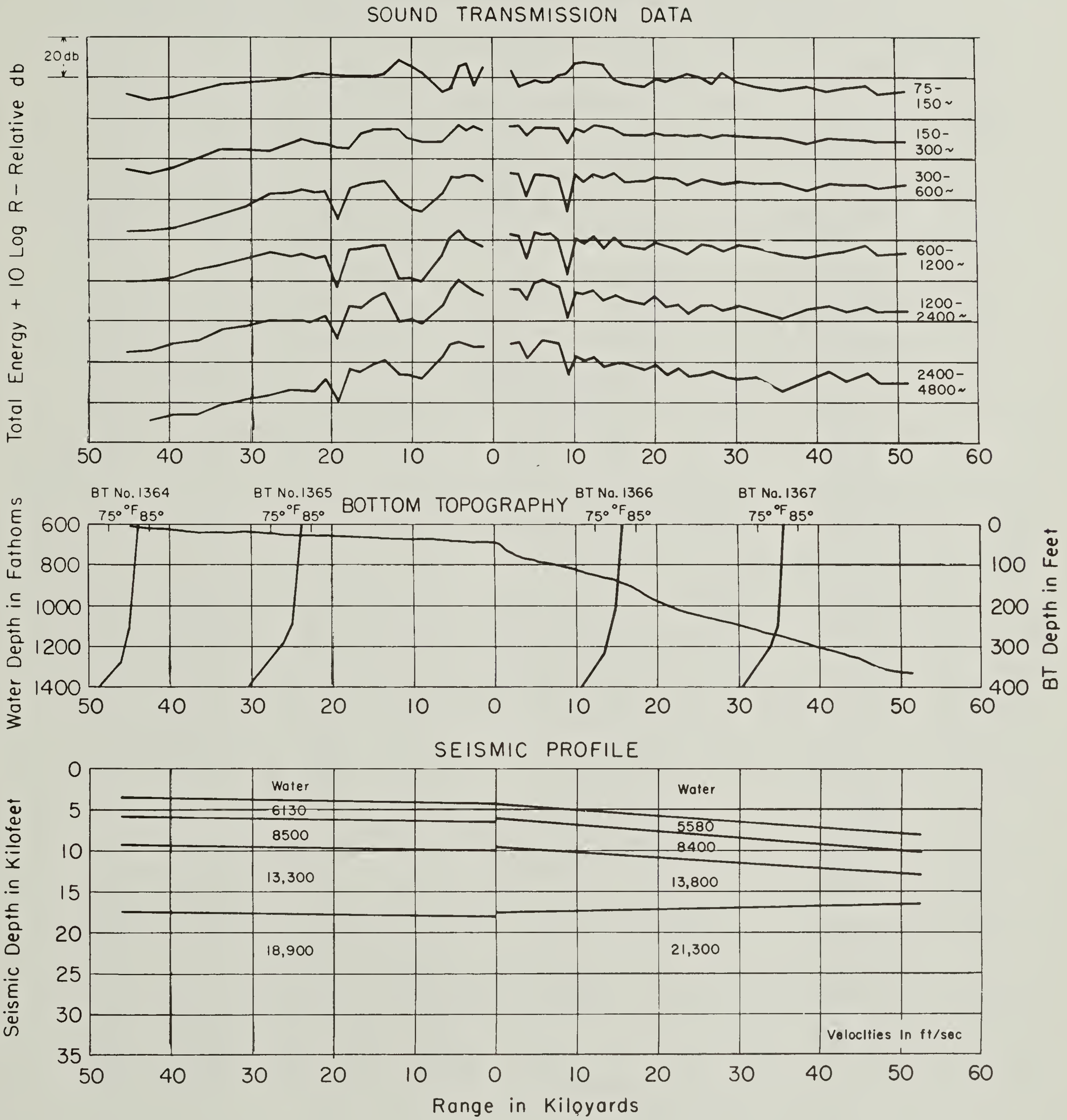
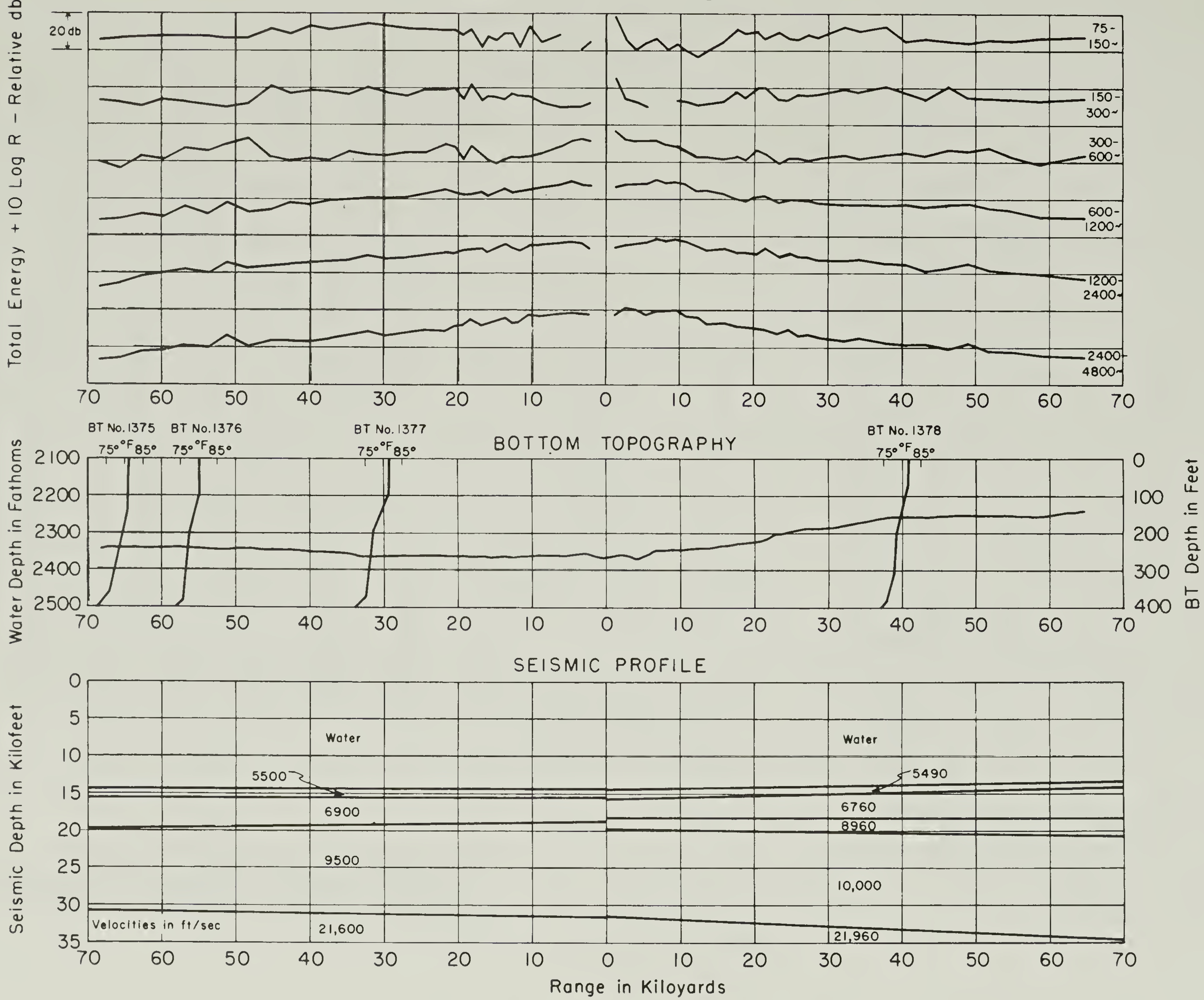

SOUND TRANSMISSION DATA
20 db
Total Energy + 10 Log R – Relative db
75-150 ~
150-300 ~
300-600 ~
600-1200 ~
1200-2400 ~
2400-4800 ~
50 40 30 20 10 0 10 20 30 40 50 60
BOTTOM TOPOGRAPHY
BT No. 1364
BT No. 1365
BT No. 1366
BT No. 1367
75° °F 85°
Water Depth in Fathoms
600 800 1000 1200 1400
BT Depth in Feet
0 100 200 300 400
SEISMIC PROFILE
Seismic Depth in Kilofeet
0 5 10 15 20 25 30 35
Water
6130
8500
13,300
18,900
Water
5580
8400
13,800
21,300
Velocities in ft/sec
Range in Kiloyards

STATION NO. 9

SOUND TRANSMISSION DATA



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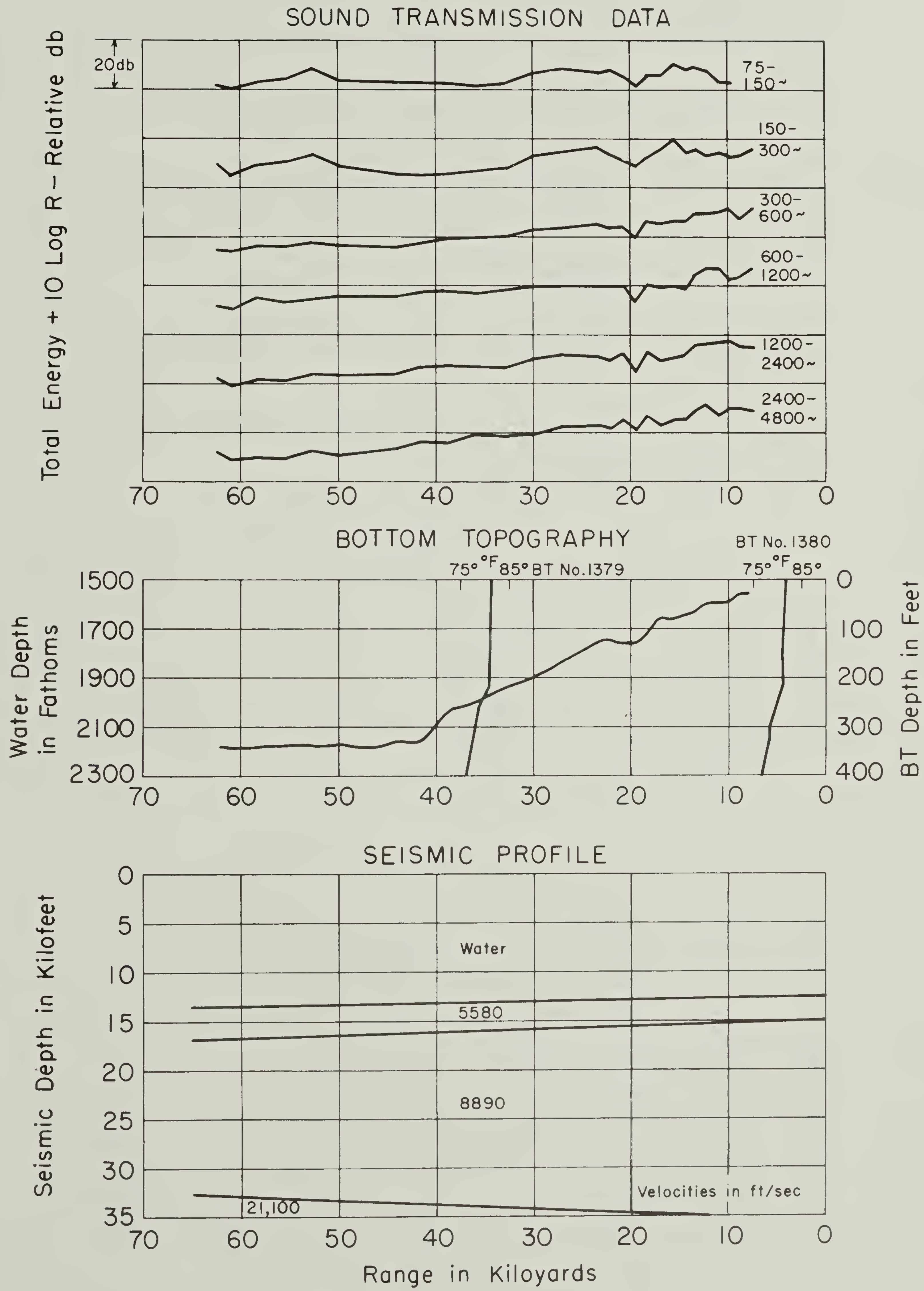

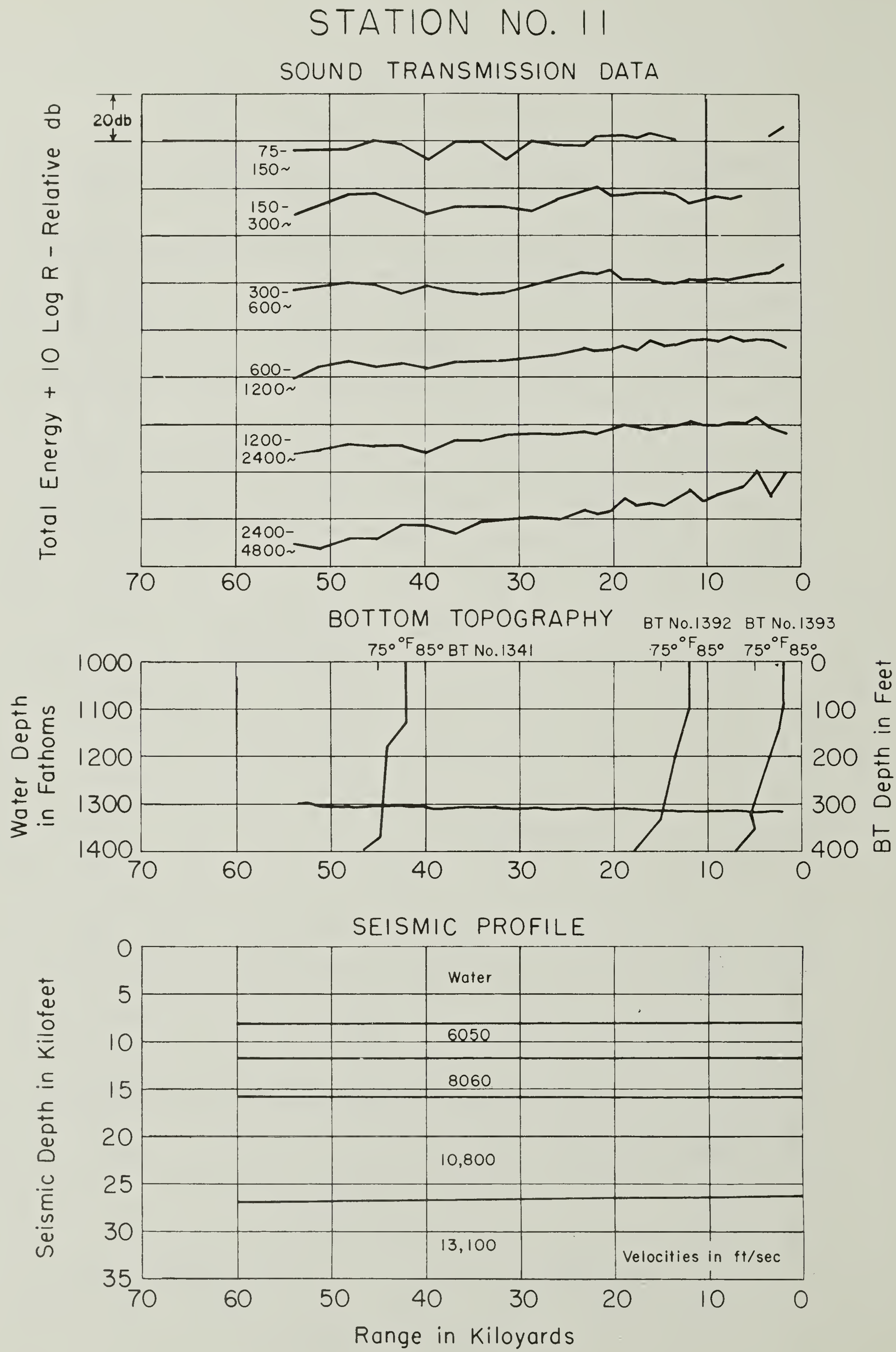

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20db
75-150~
150-300~
300-600~
600-1200~
1200-2400~
2400-4800~
70 60 50 40 30 20 10 0
BOTTOM TOPOGRAPHY
75° °F 85° BT No.1341
BT No.1392 75° °F 85°
BT No.1393 75° °F 85°
Water Depth in Fathoms
1000 1100 1200 1300 1400
BT Depth in Feet
0 100 200 300 400
70 60 50 40 30 20 10 0
SEISMIC PROFILE
Seismic Depth in Kilofeet
0 5 10 15 20 25 30 35
Water
6050
8060
10,800
13,100
Velocities in ft/sec
70 60 50 40 30 20 10 0
Range in Kiloyards

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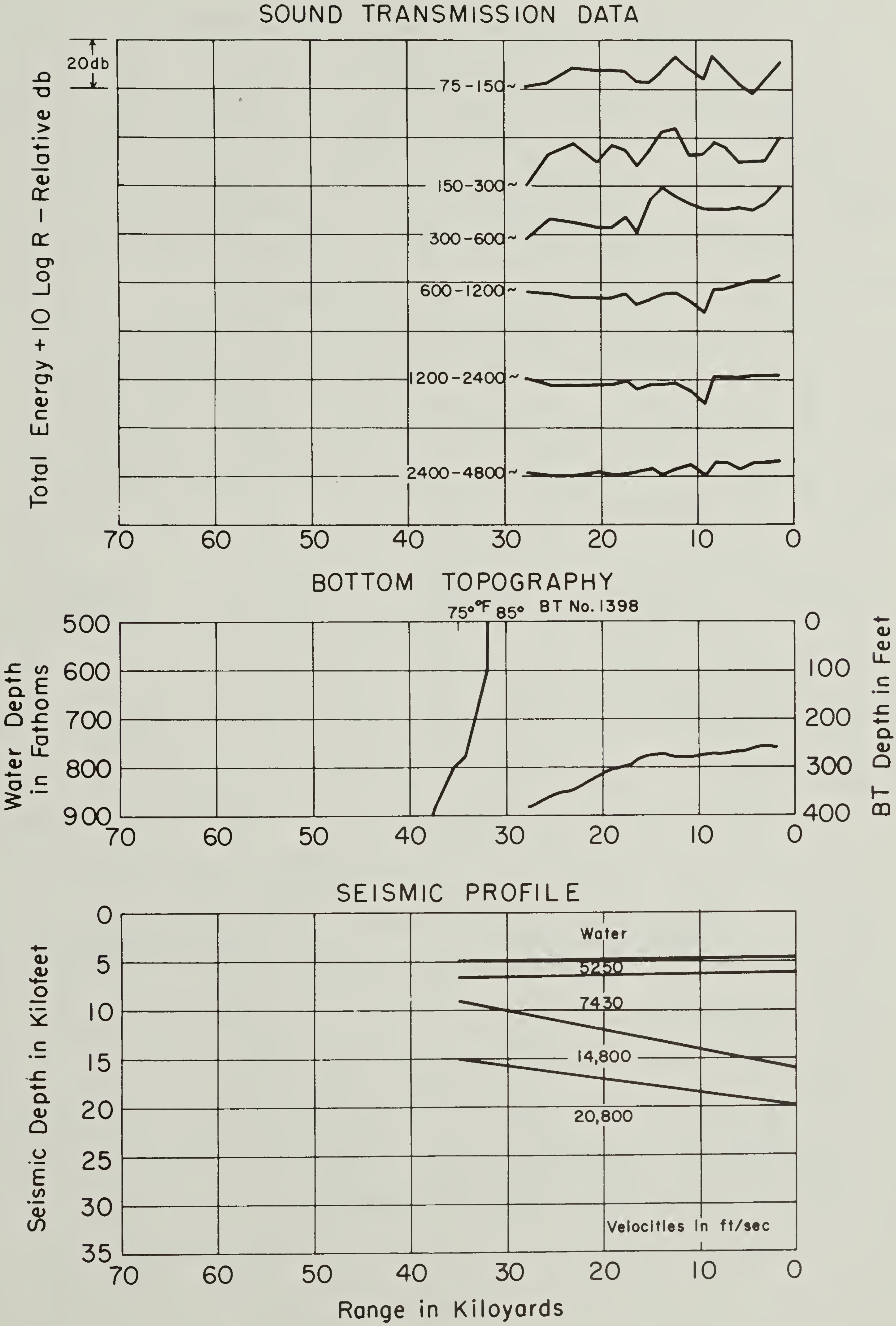

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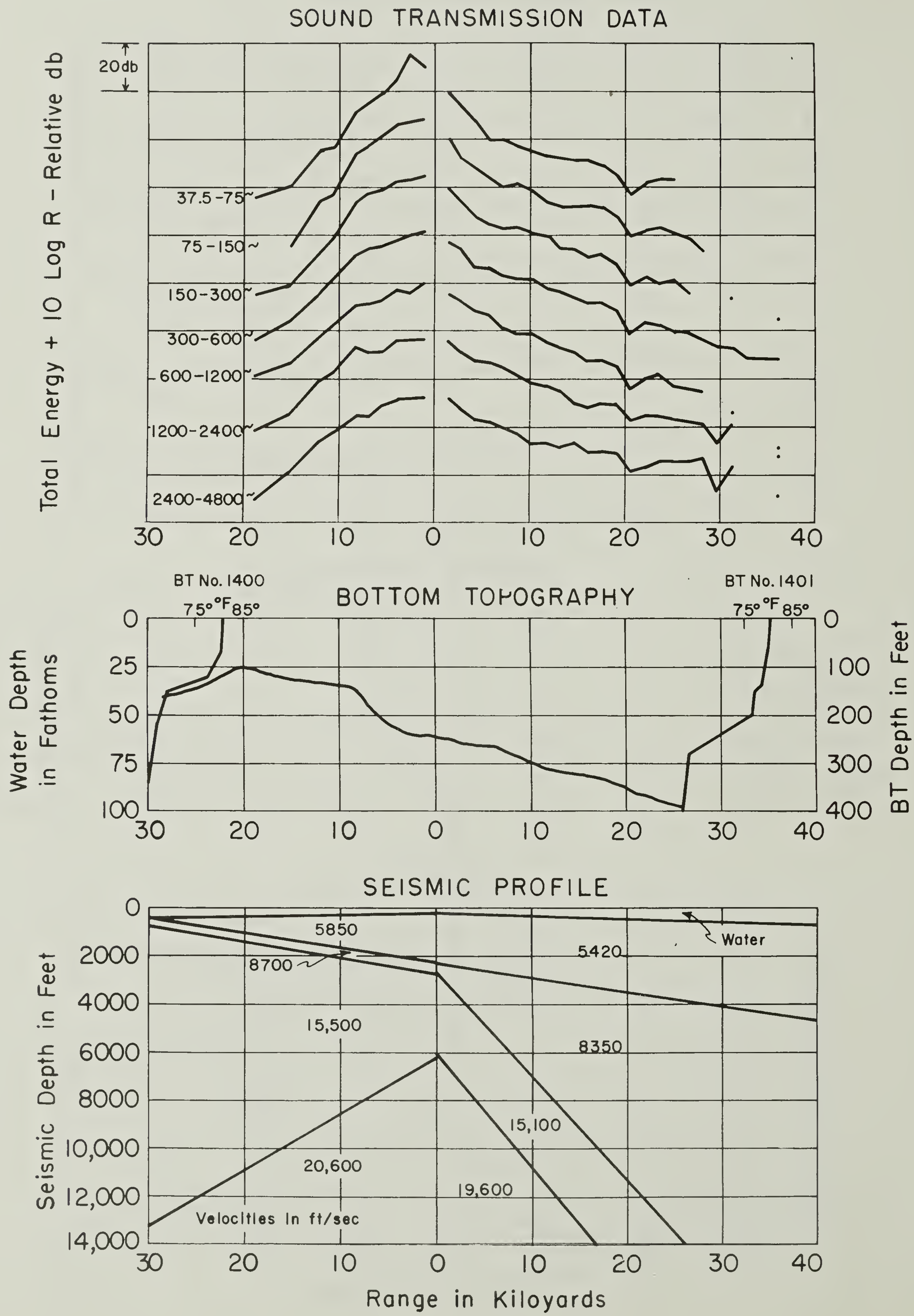

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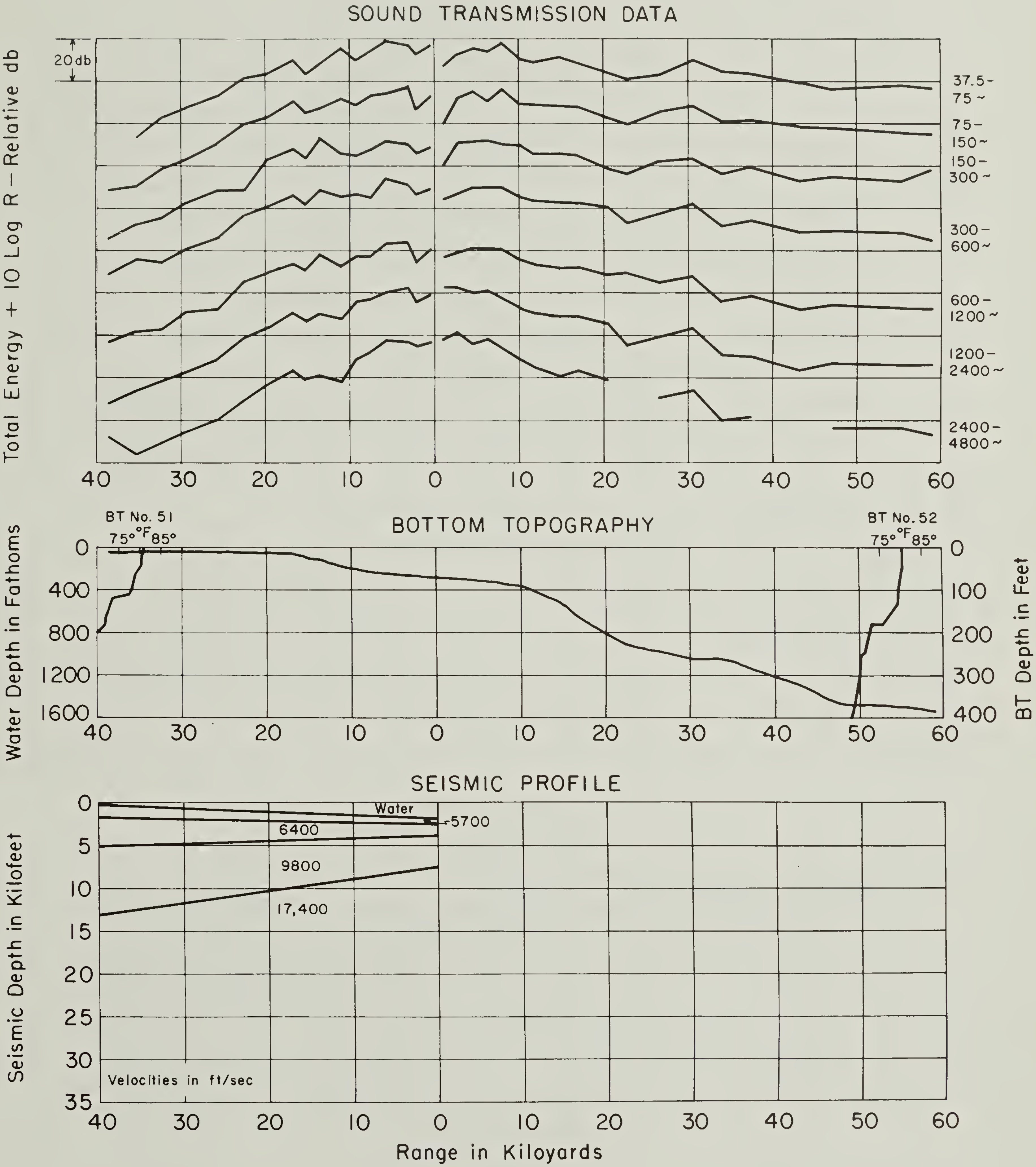

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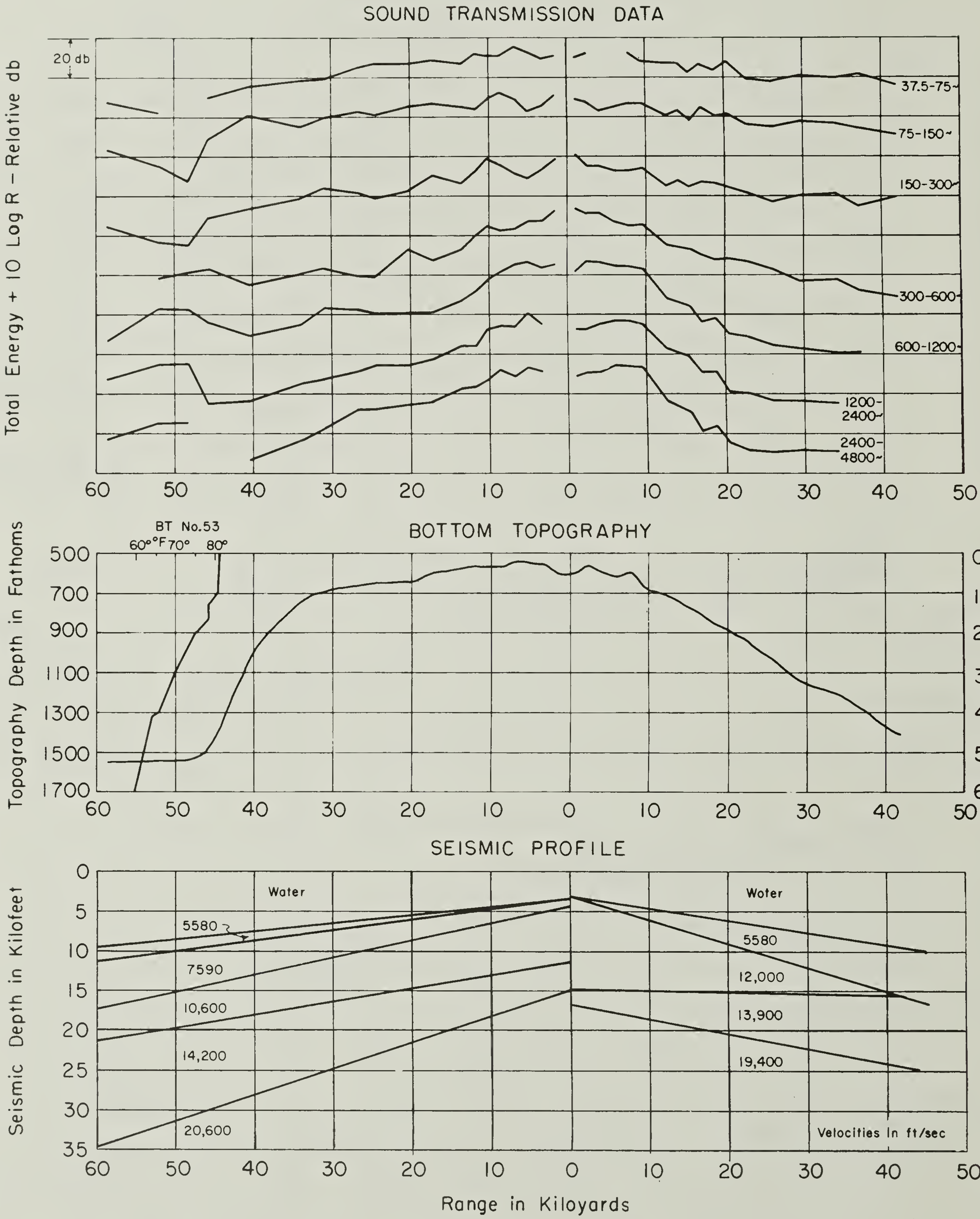

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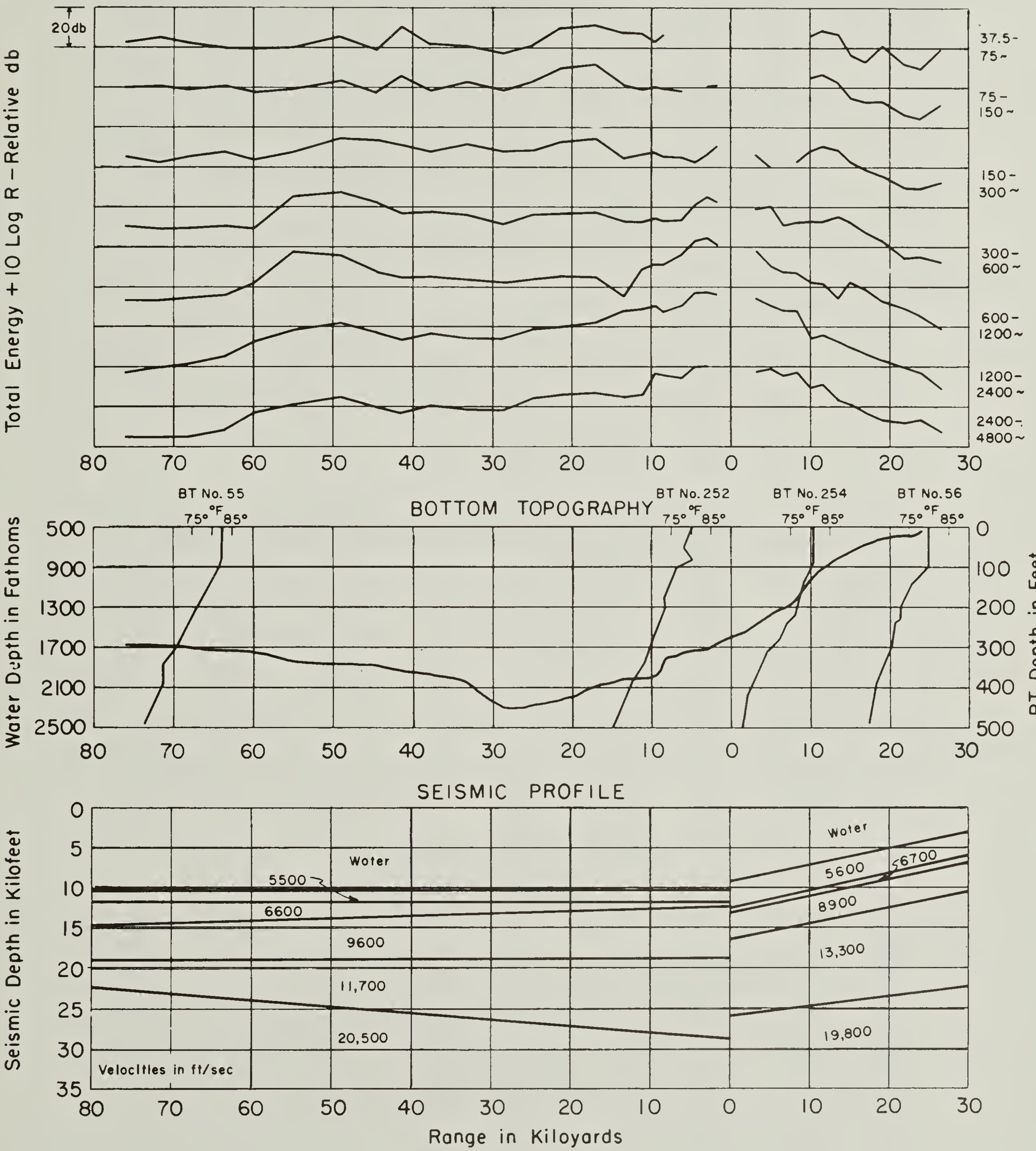

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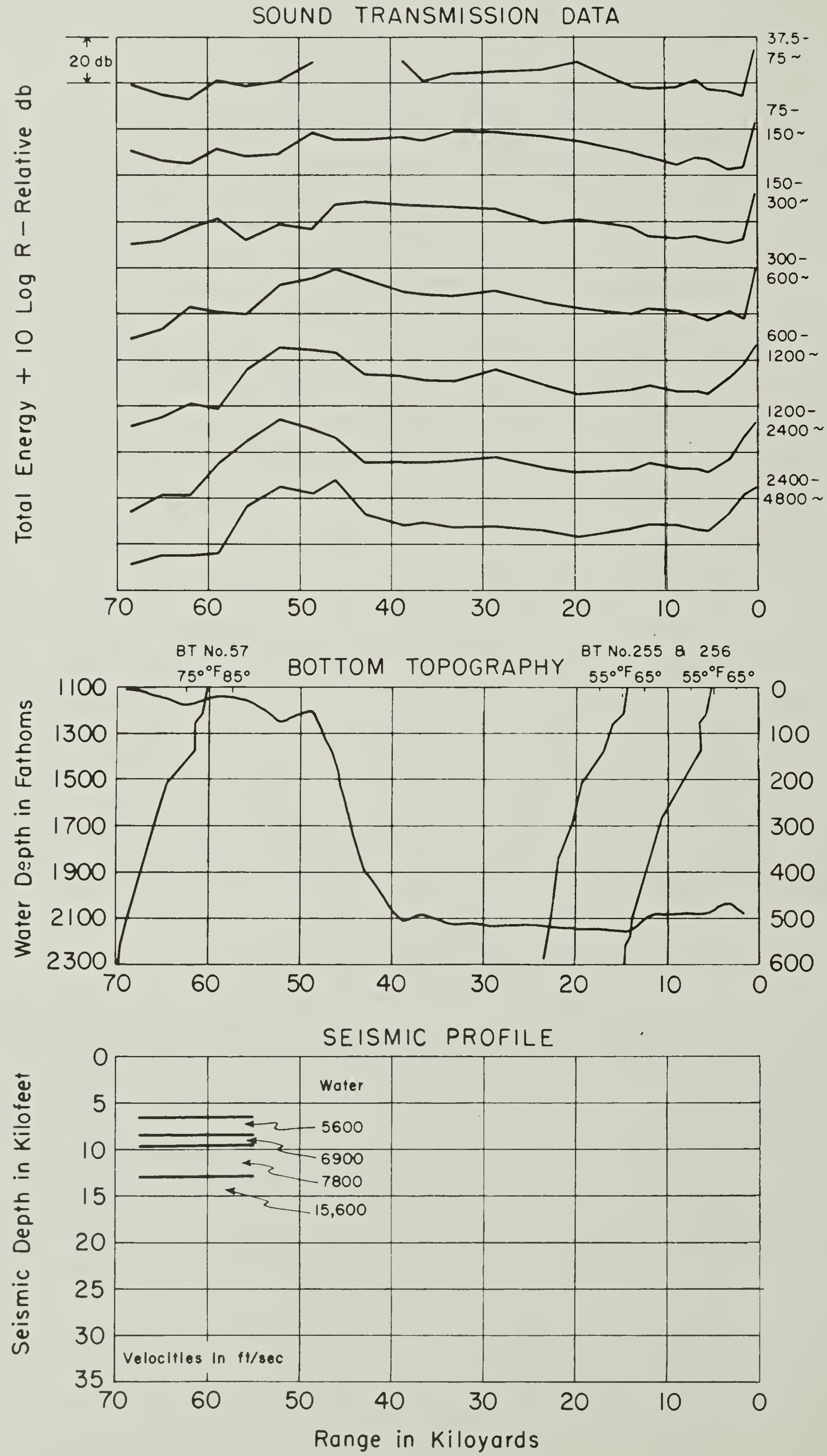

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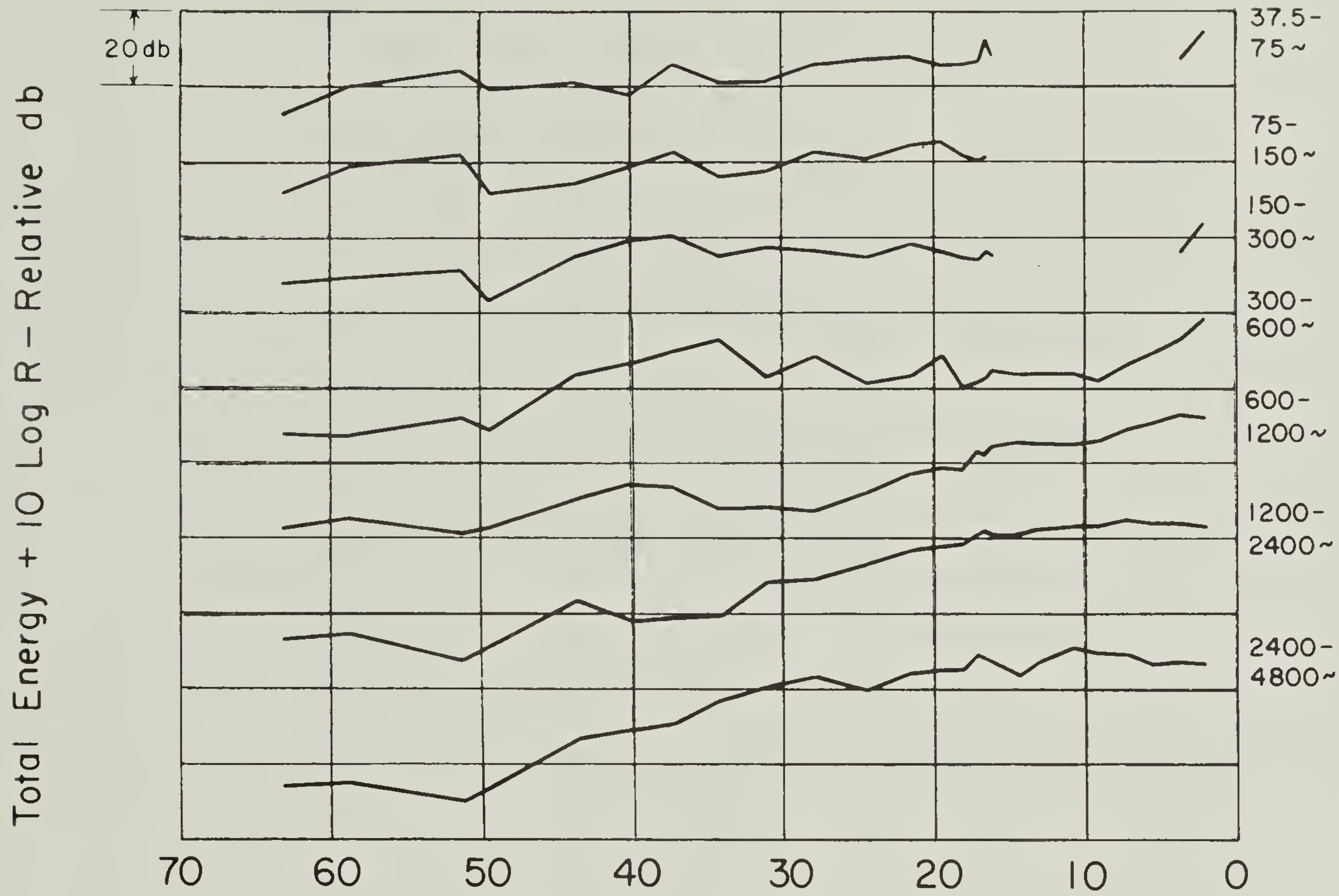

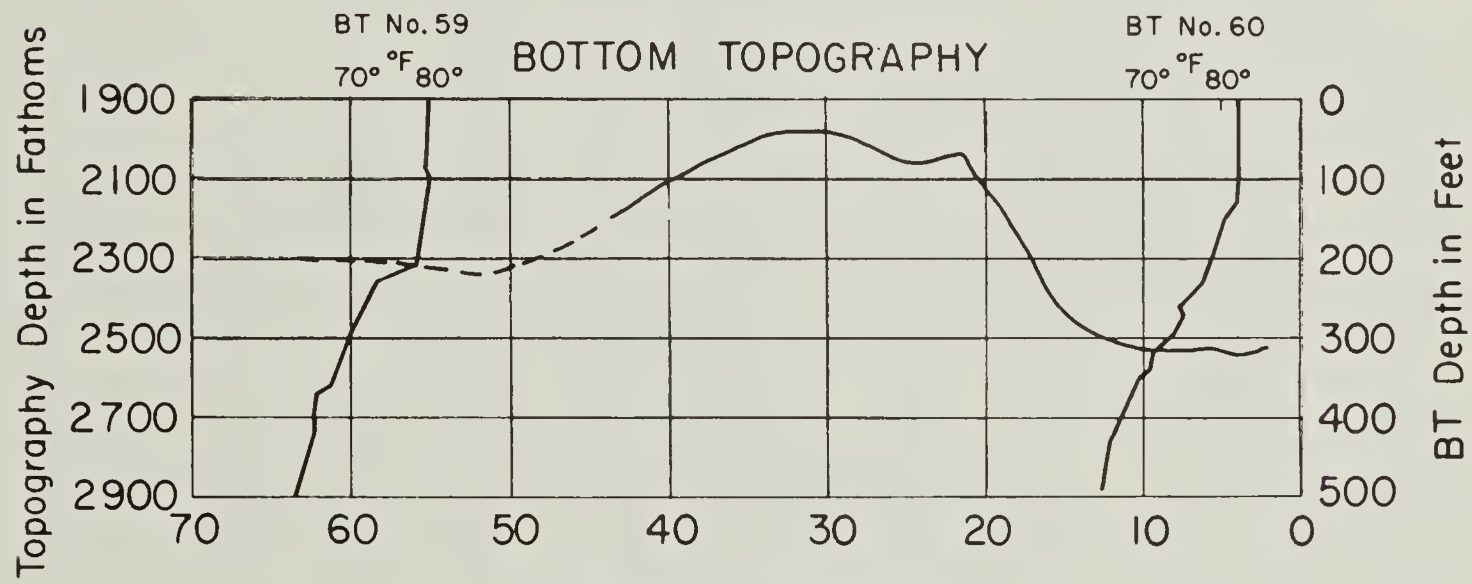

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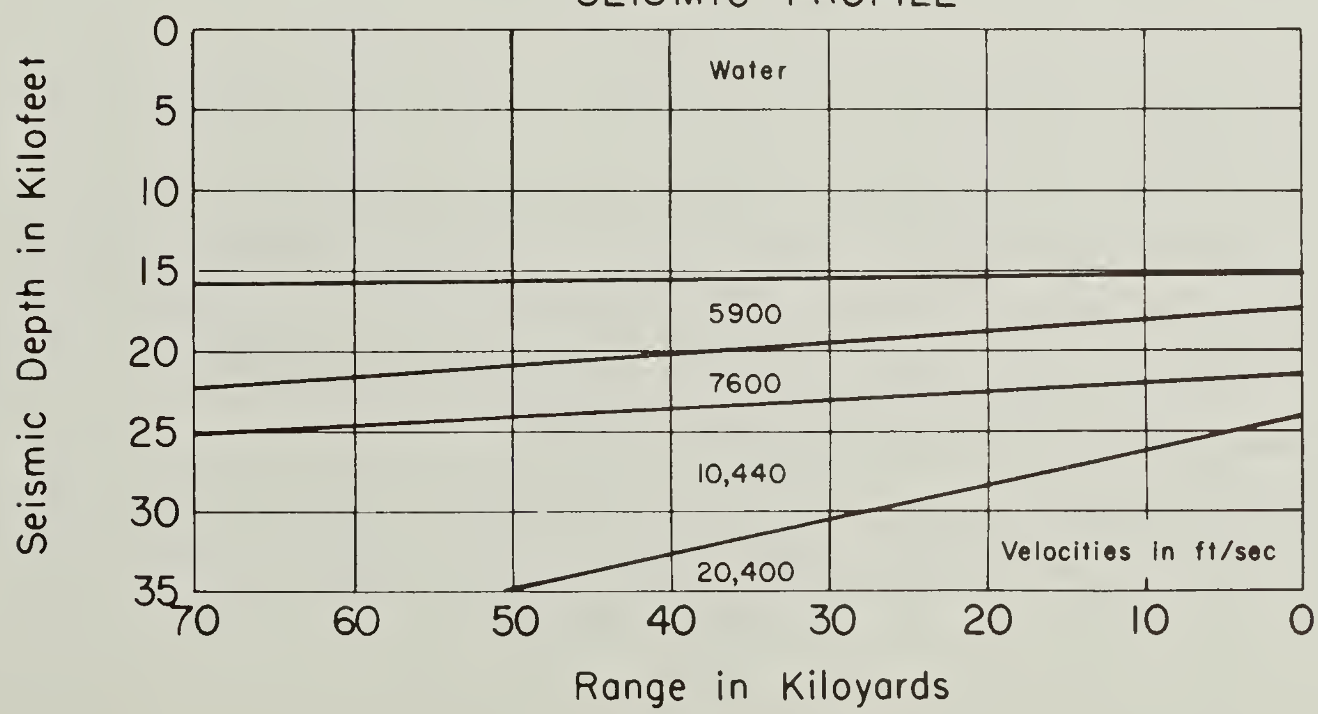

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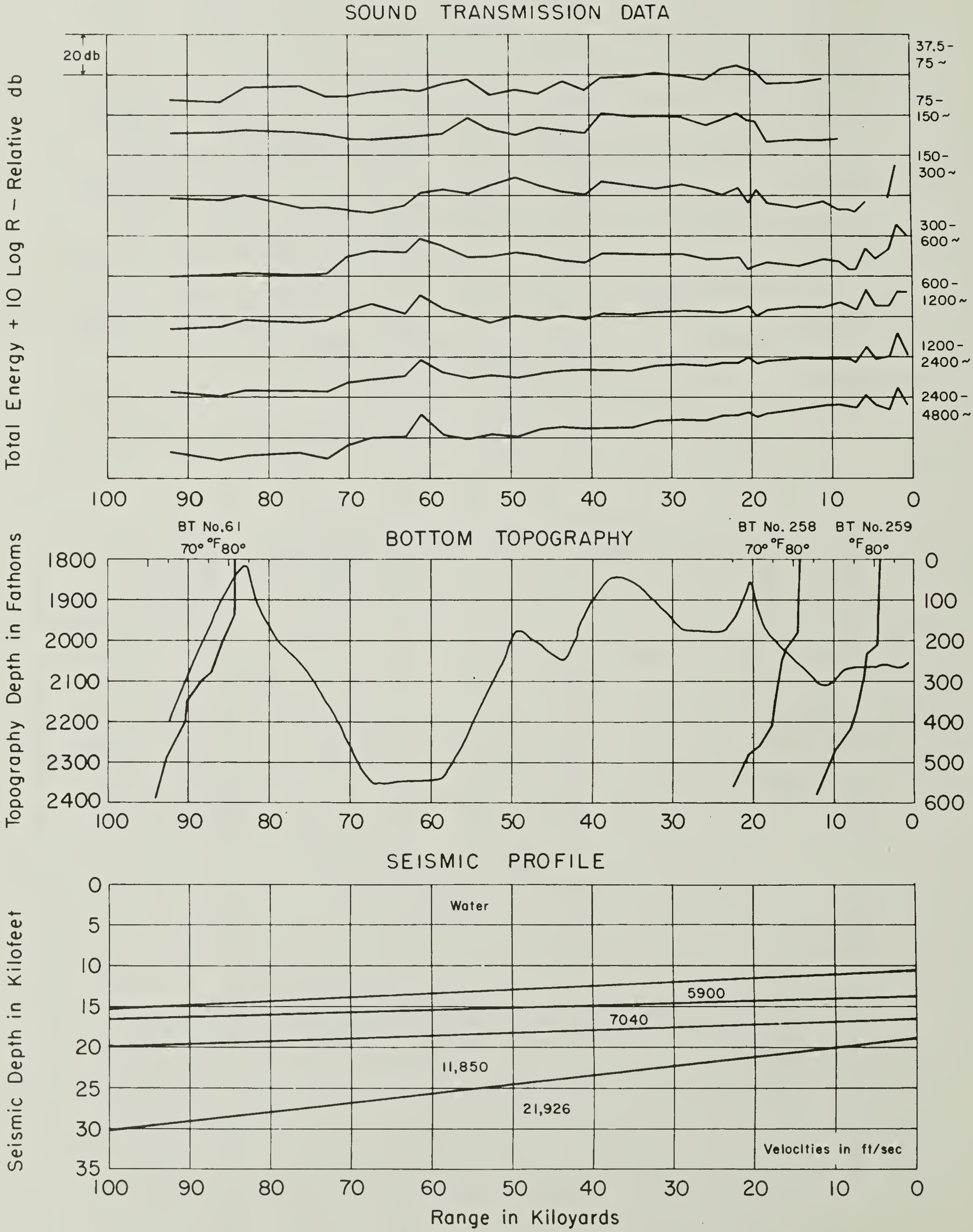

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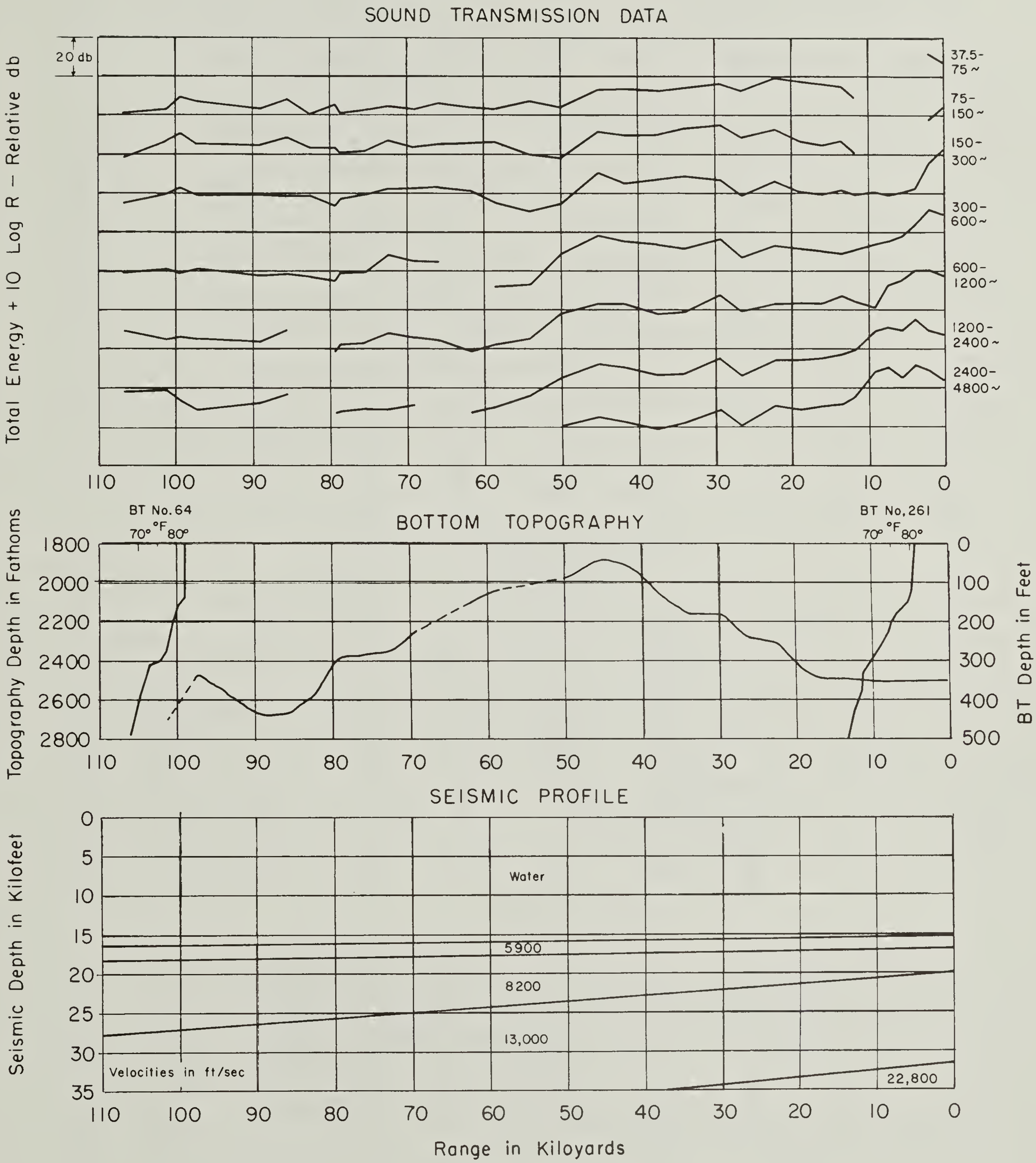

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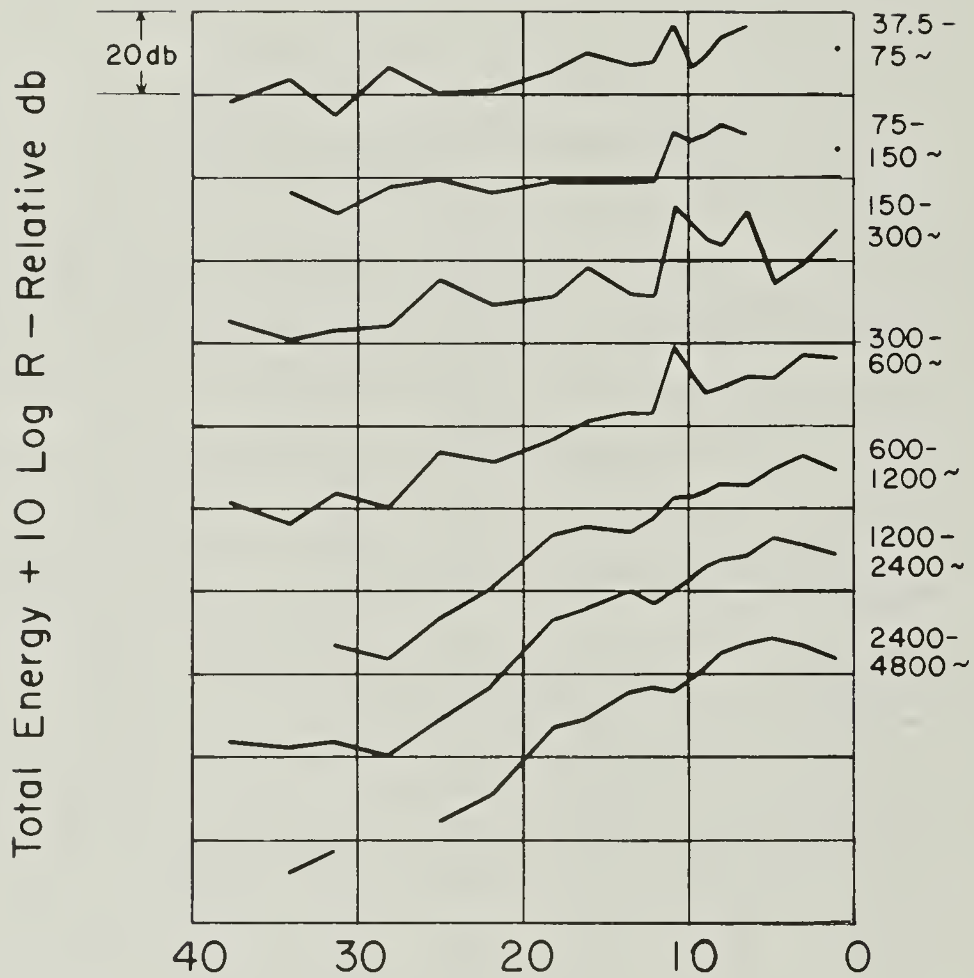

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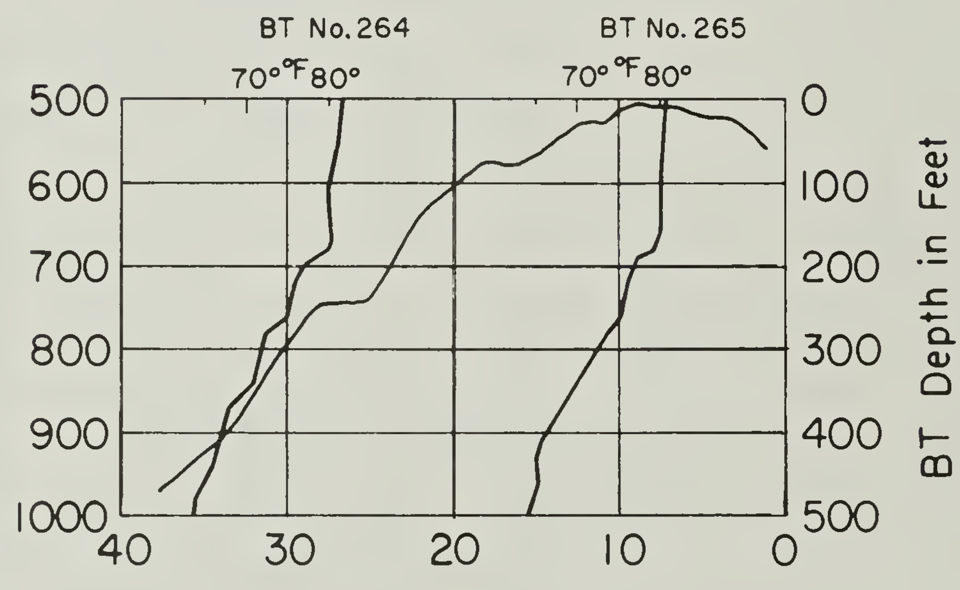

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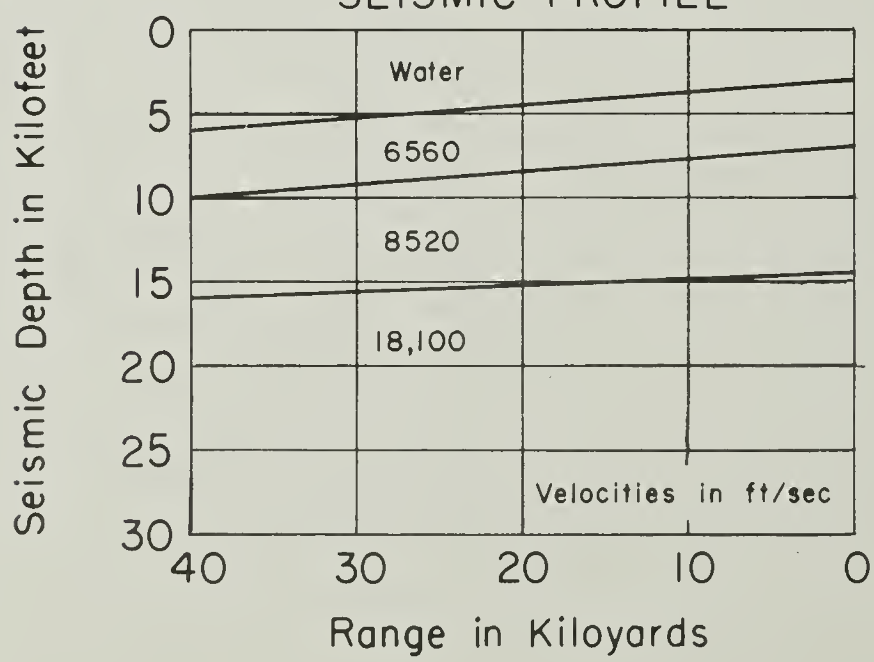

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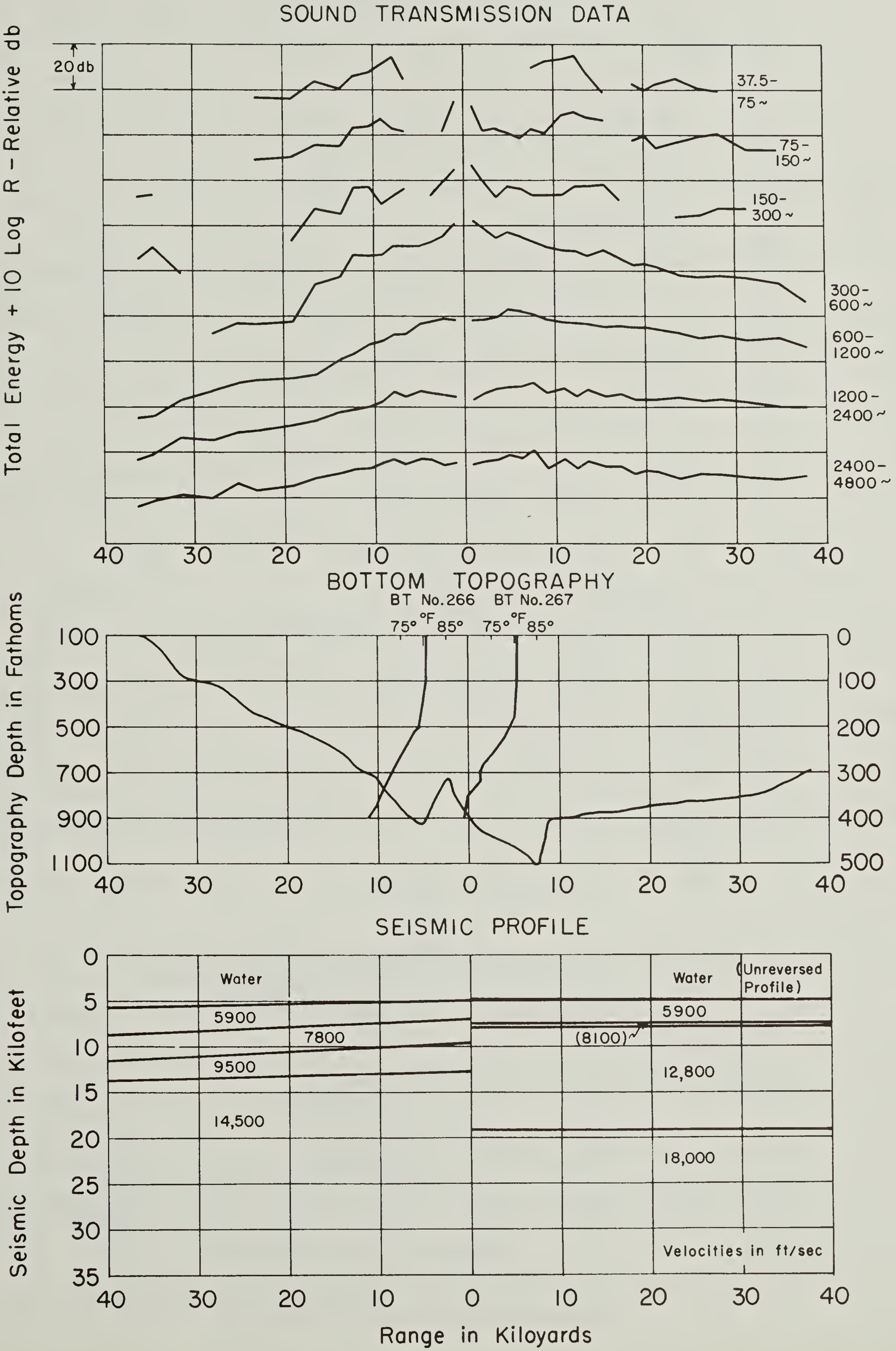

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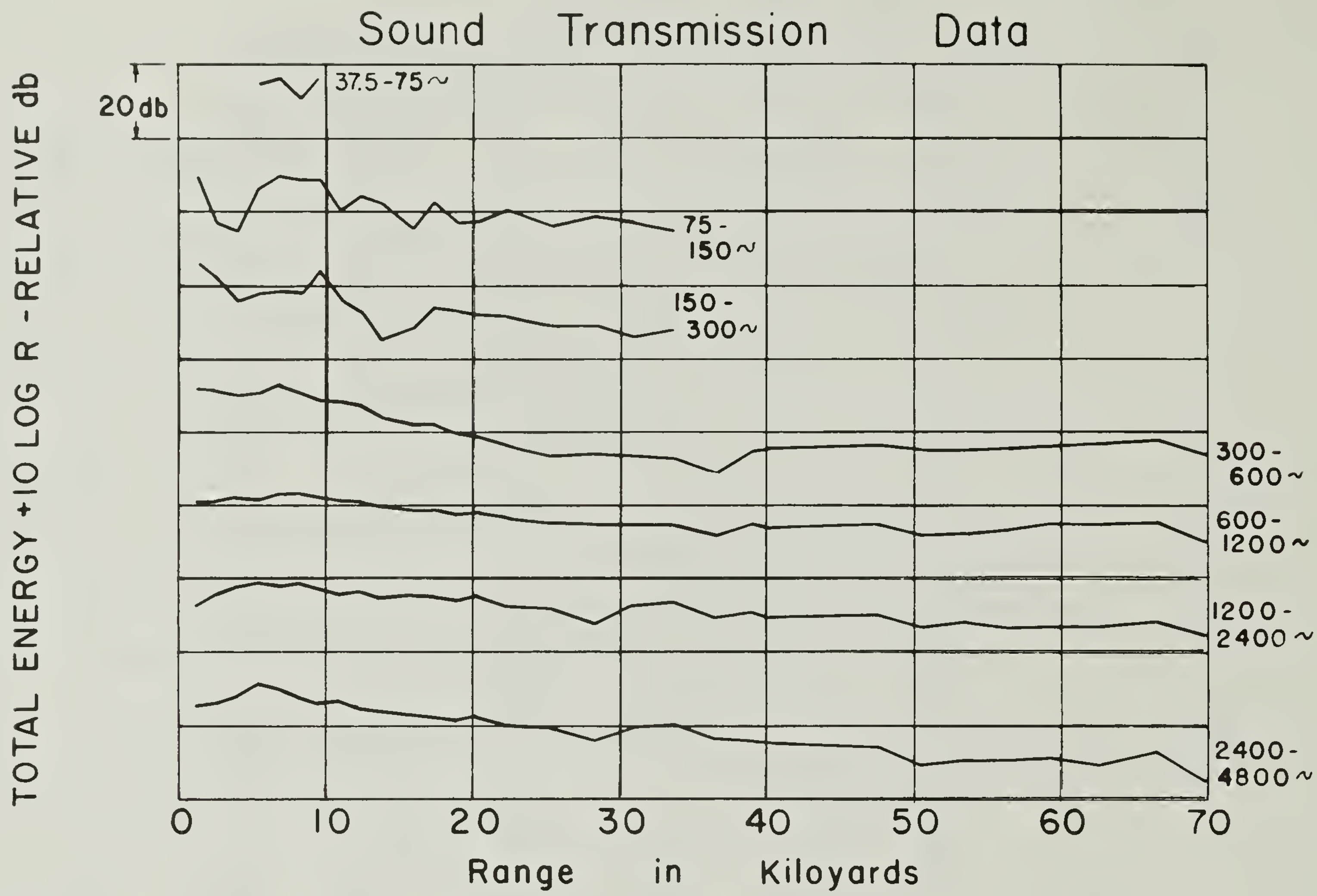
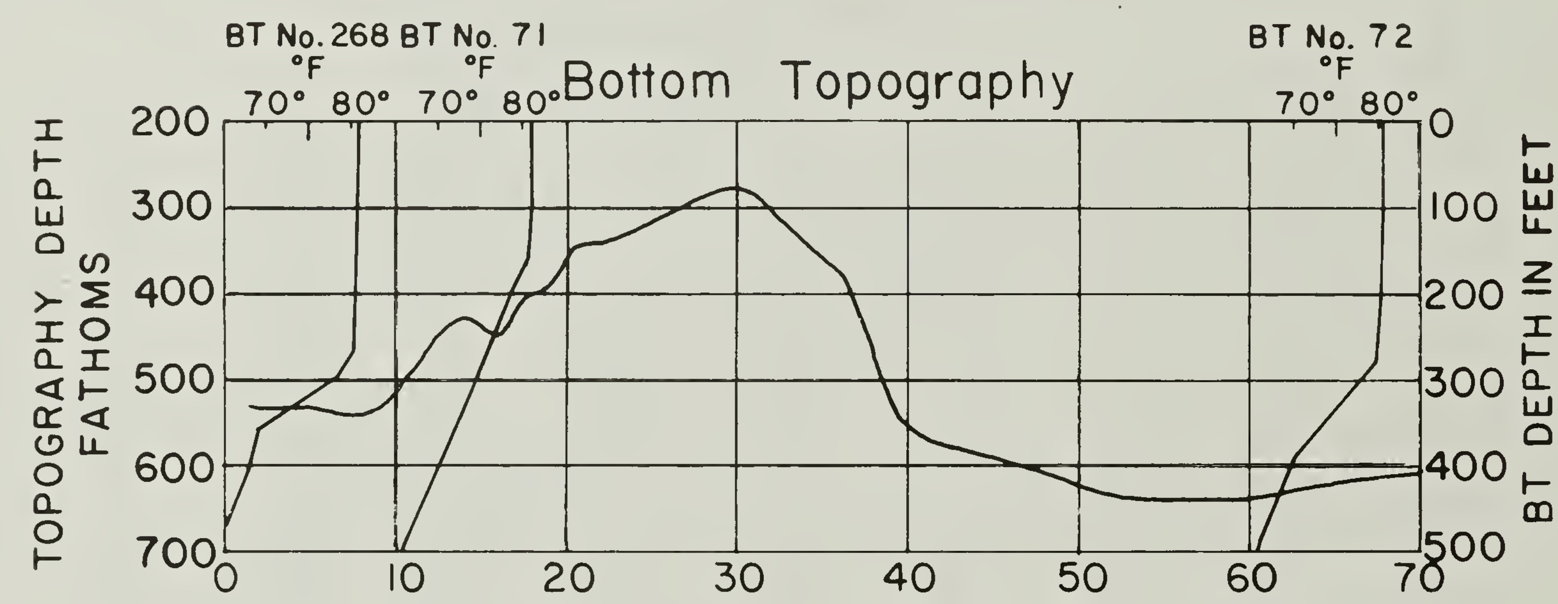
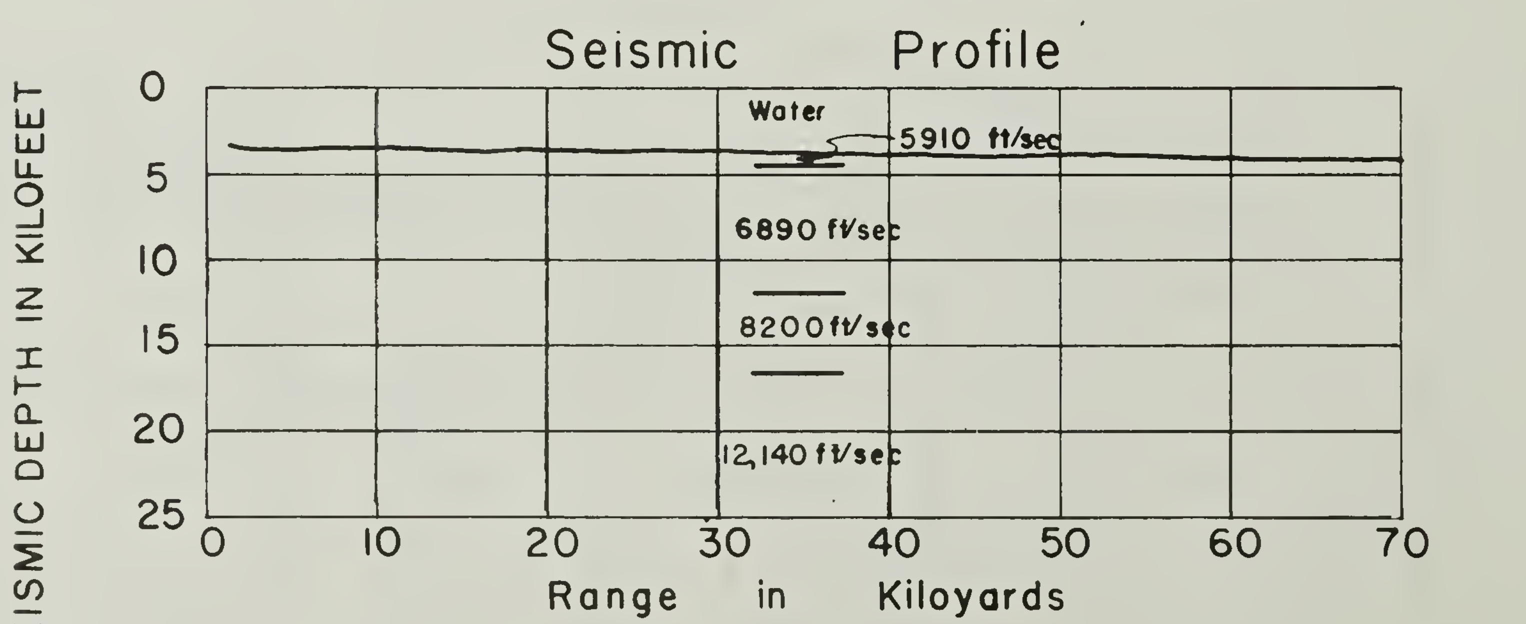
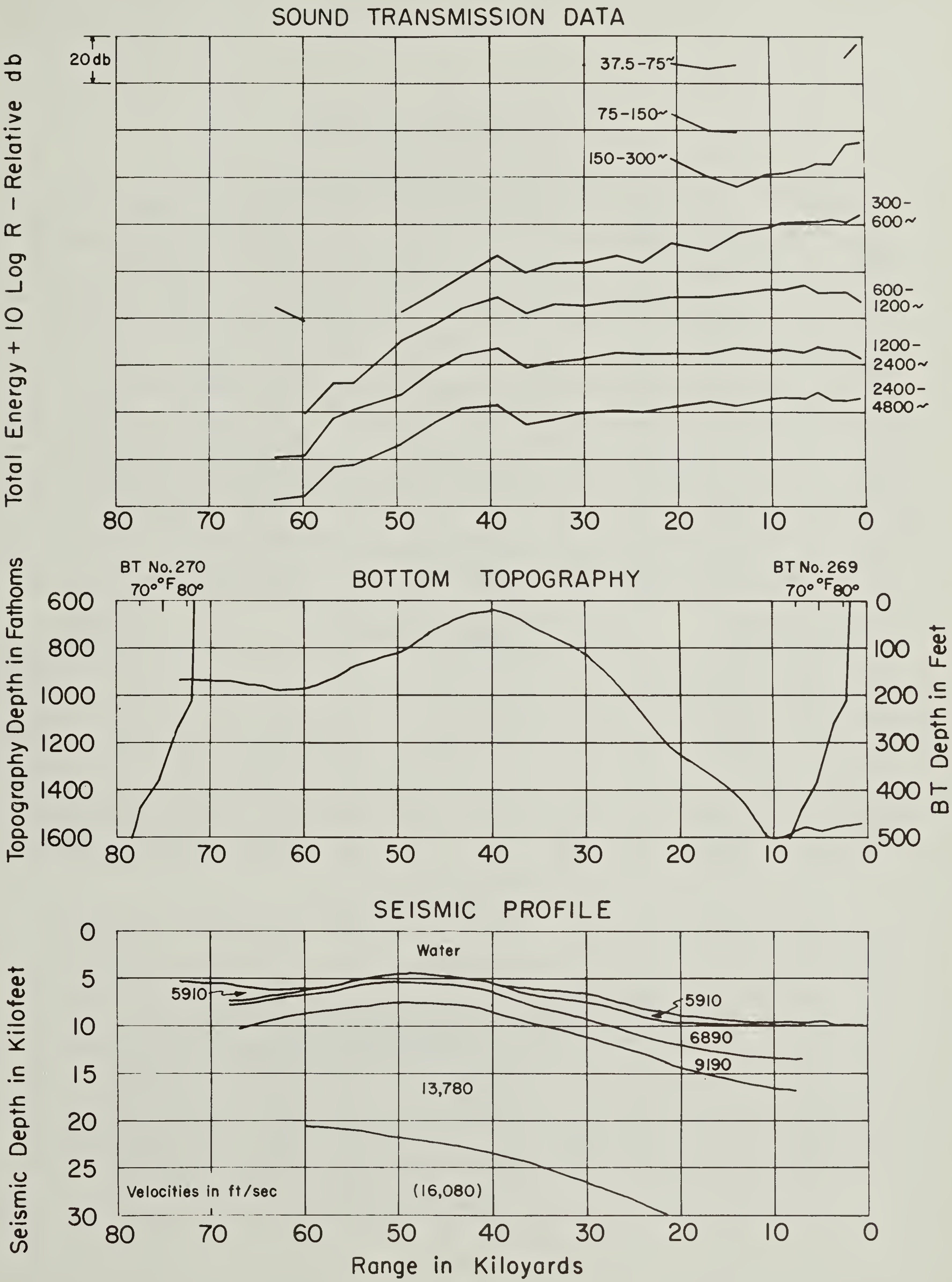






Note: Energy curves are spaced for clarity and do not represent their relative energies

STATION NO. 26



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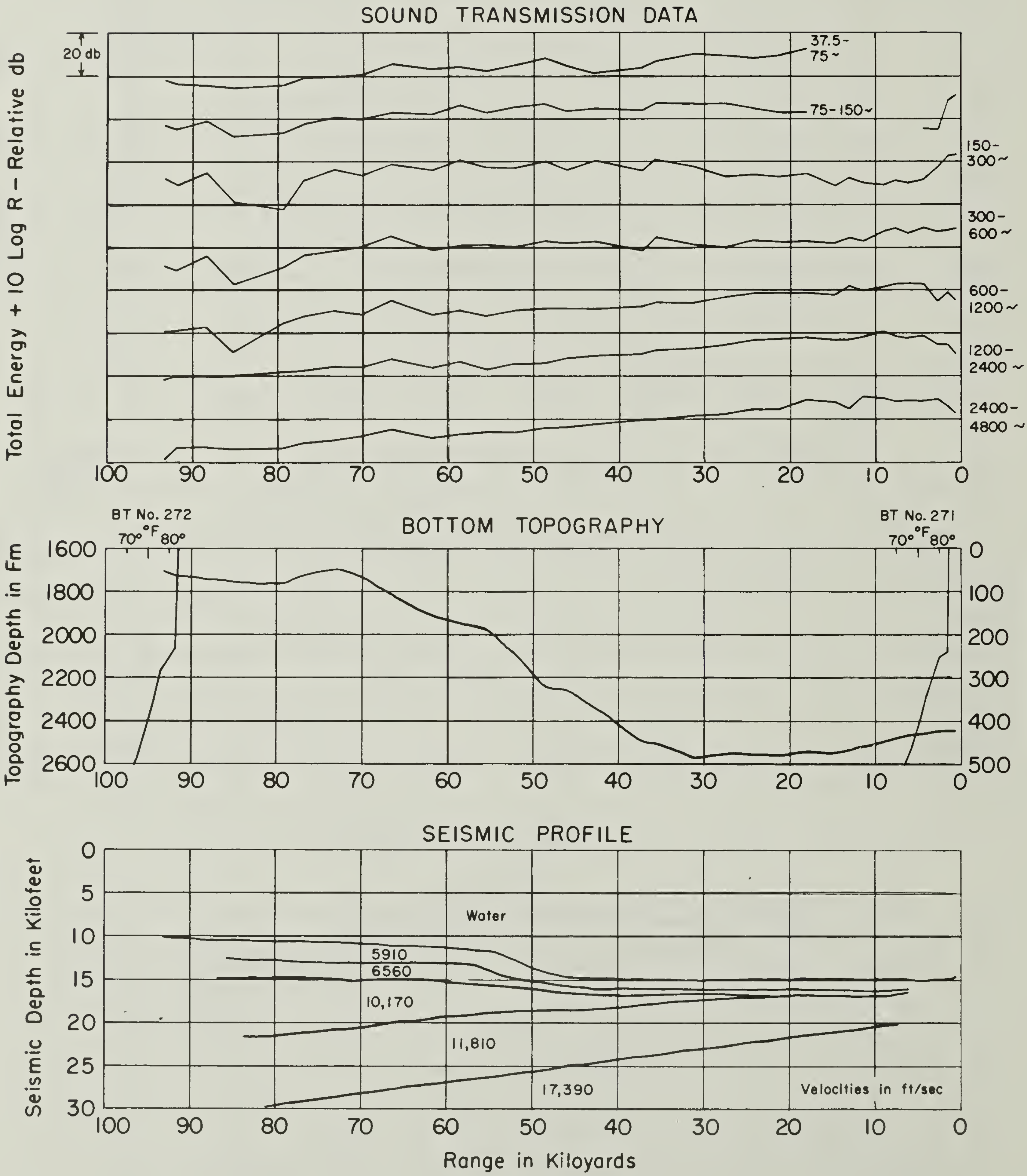

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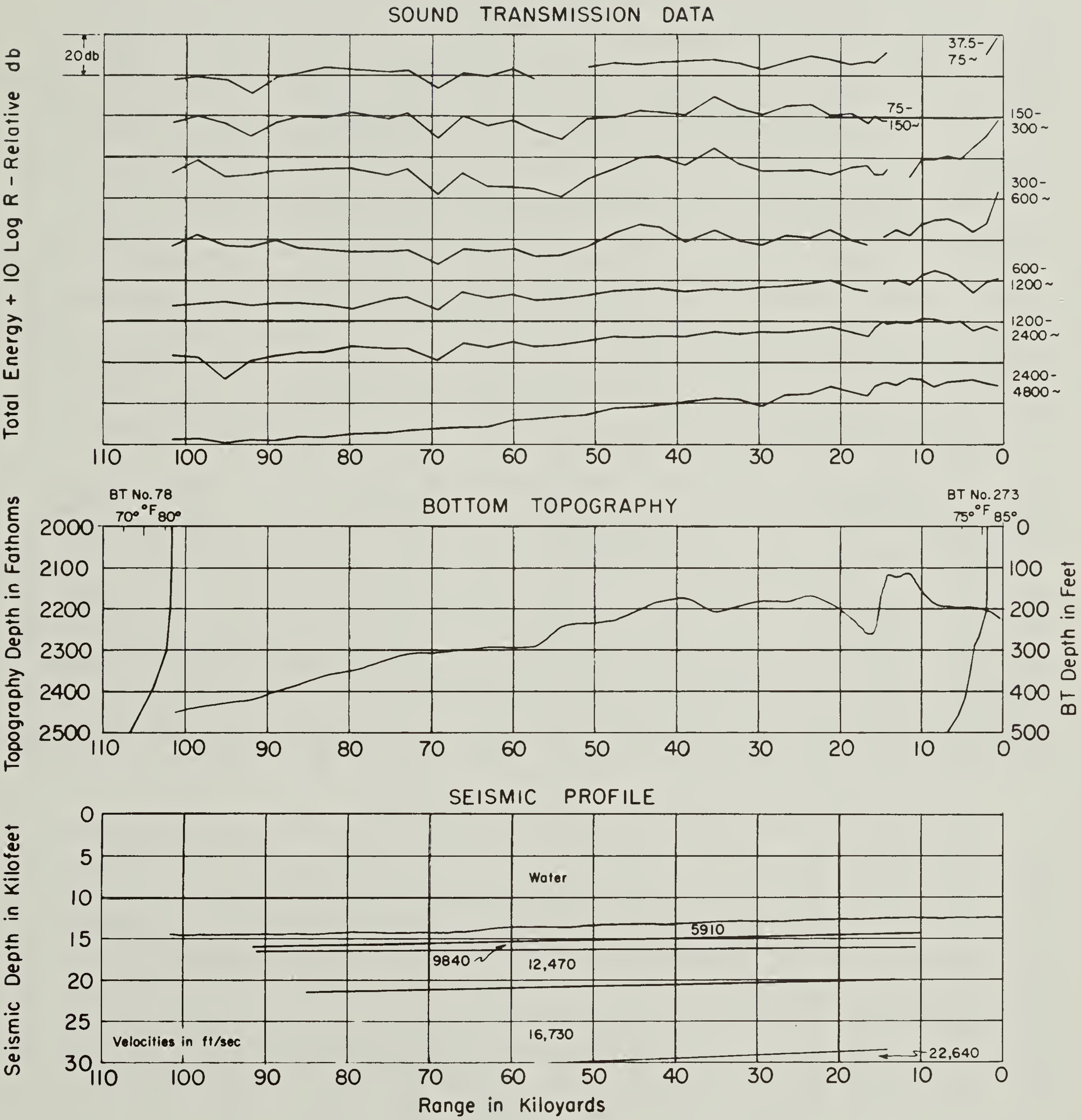

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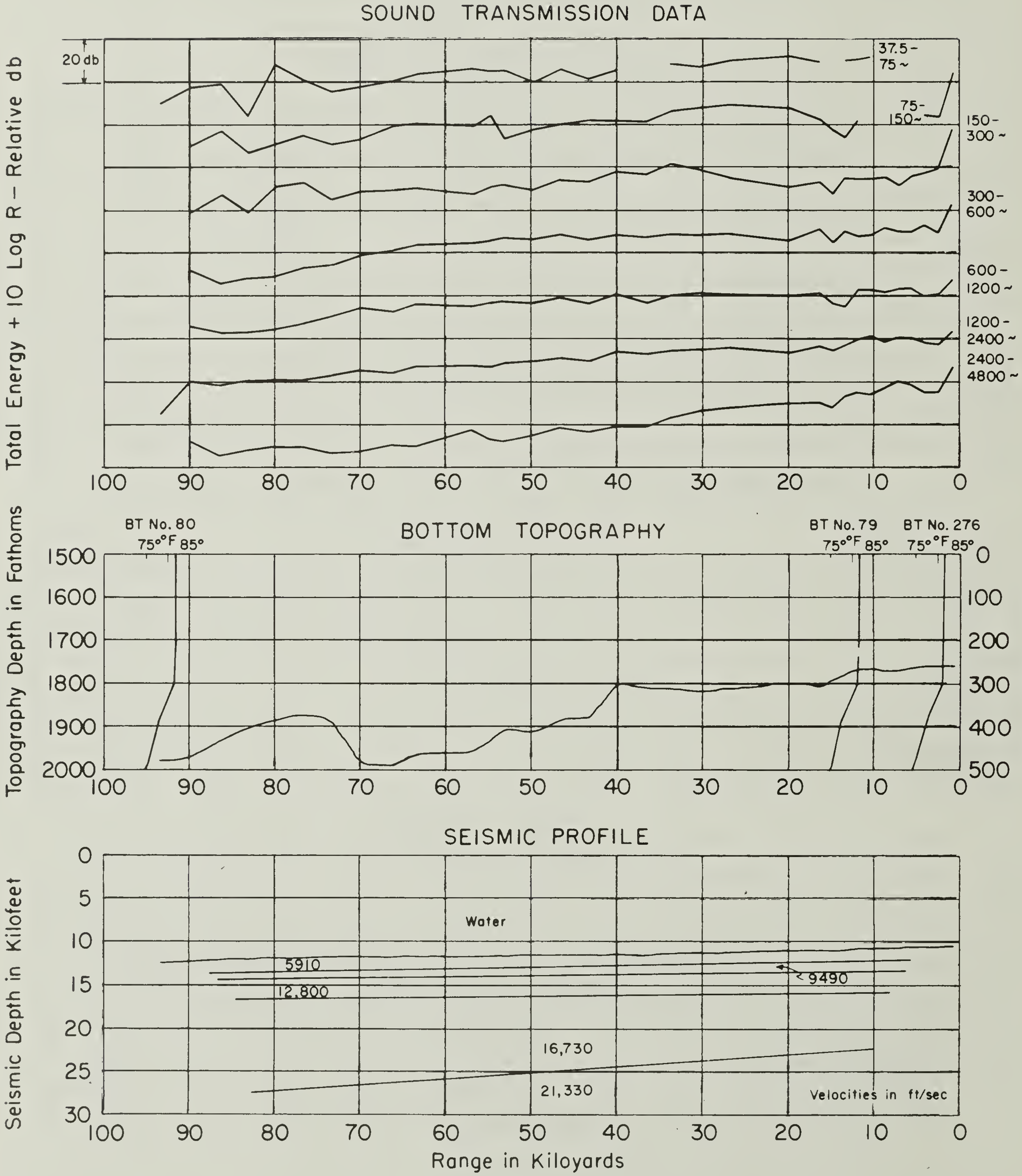
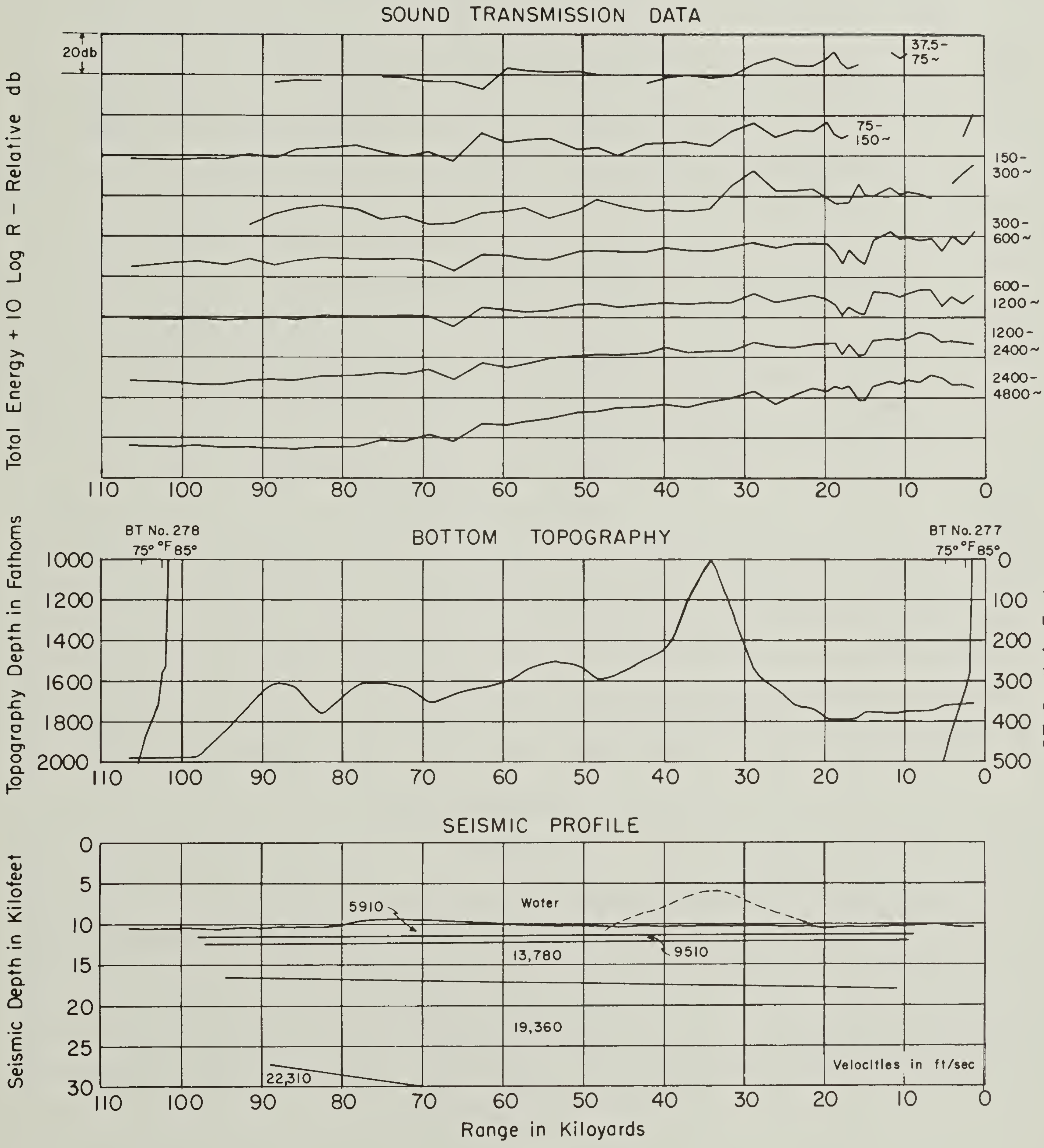
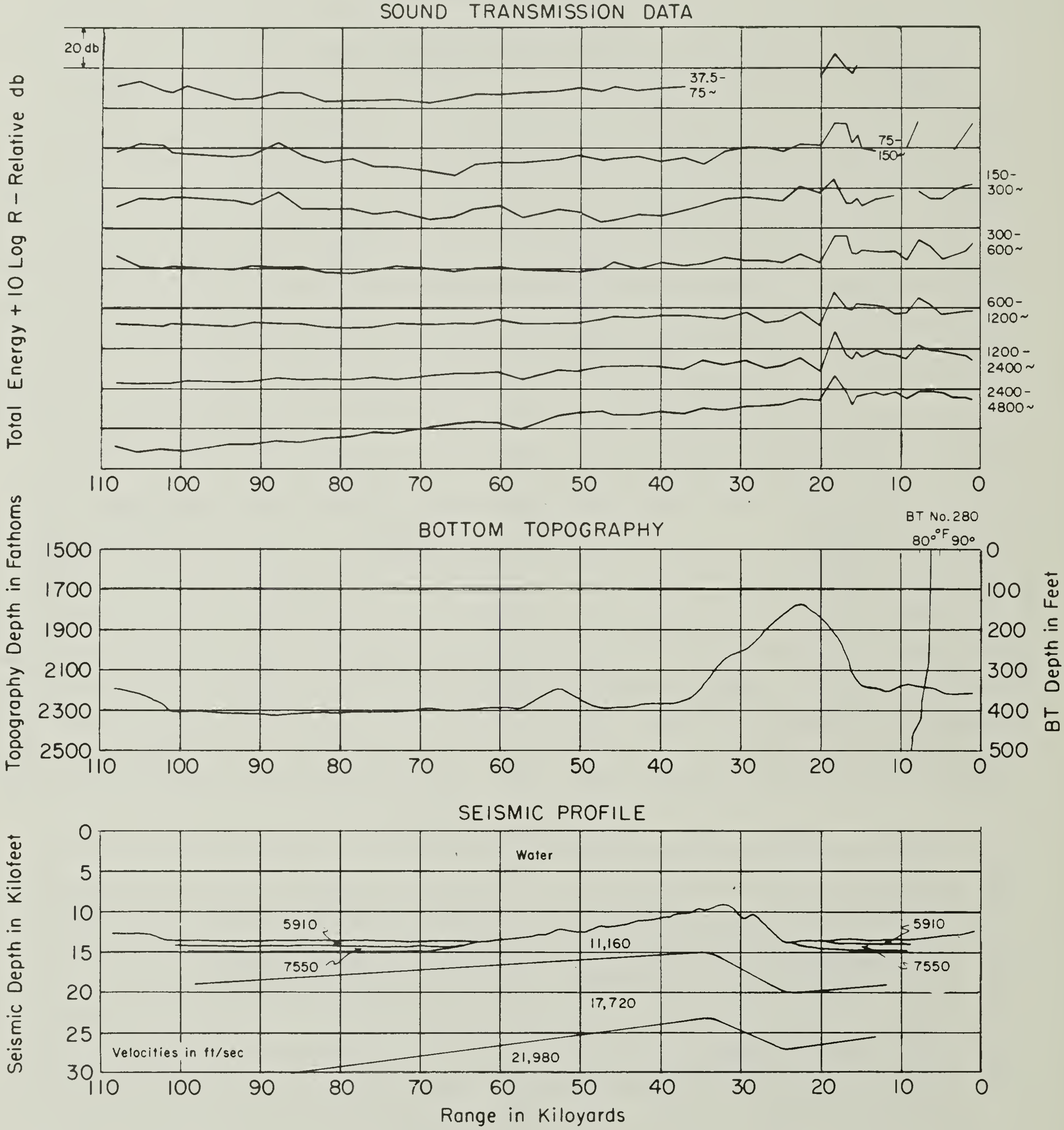


STATION NO. 30



STATION NO. 31



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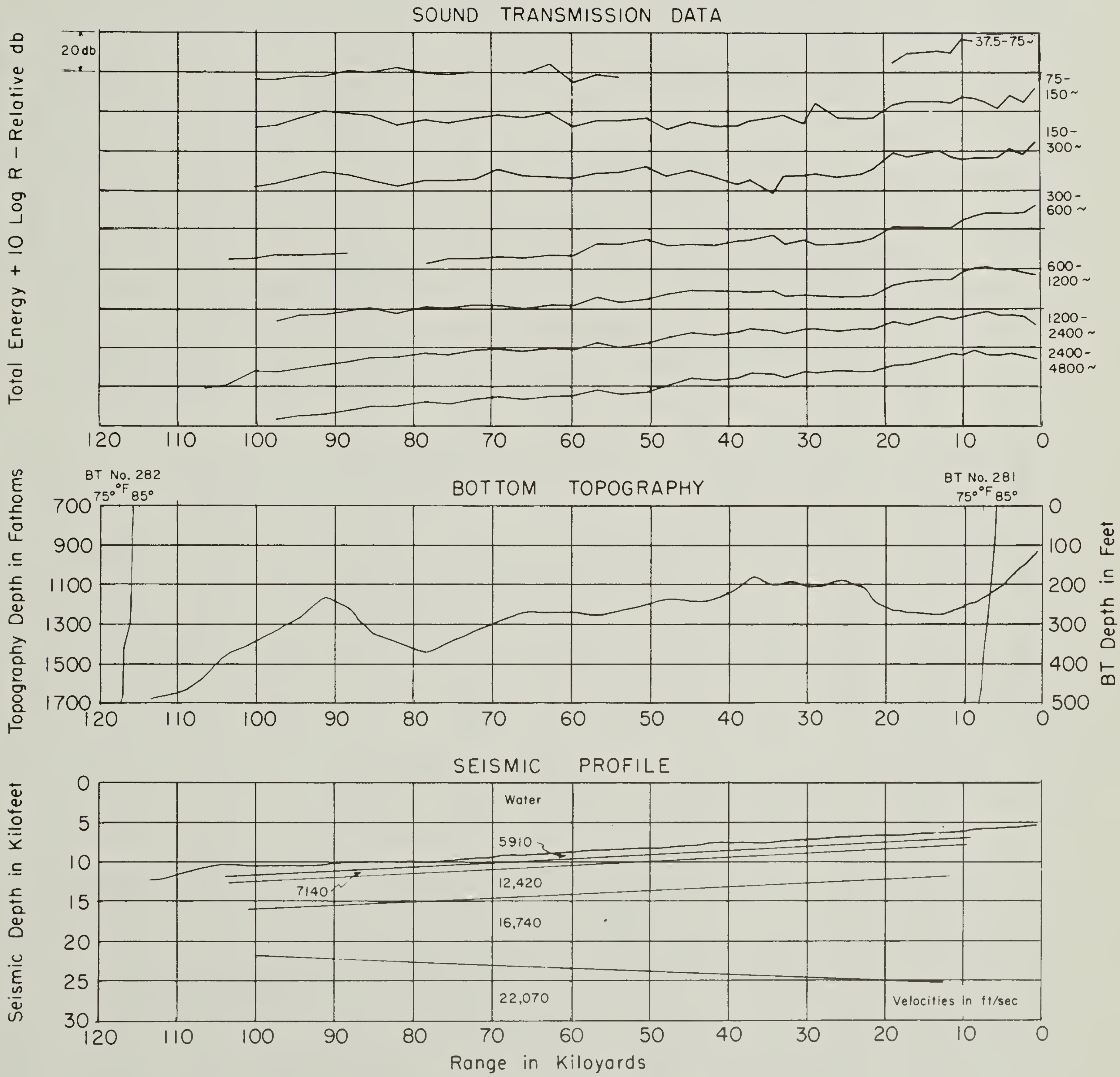

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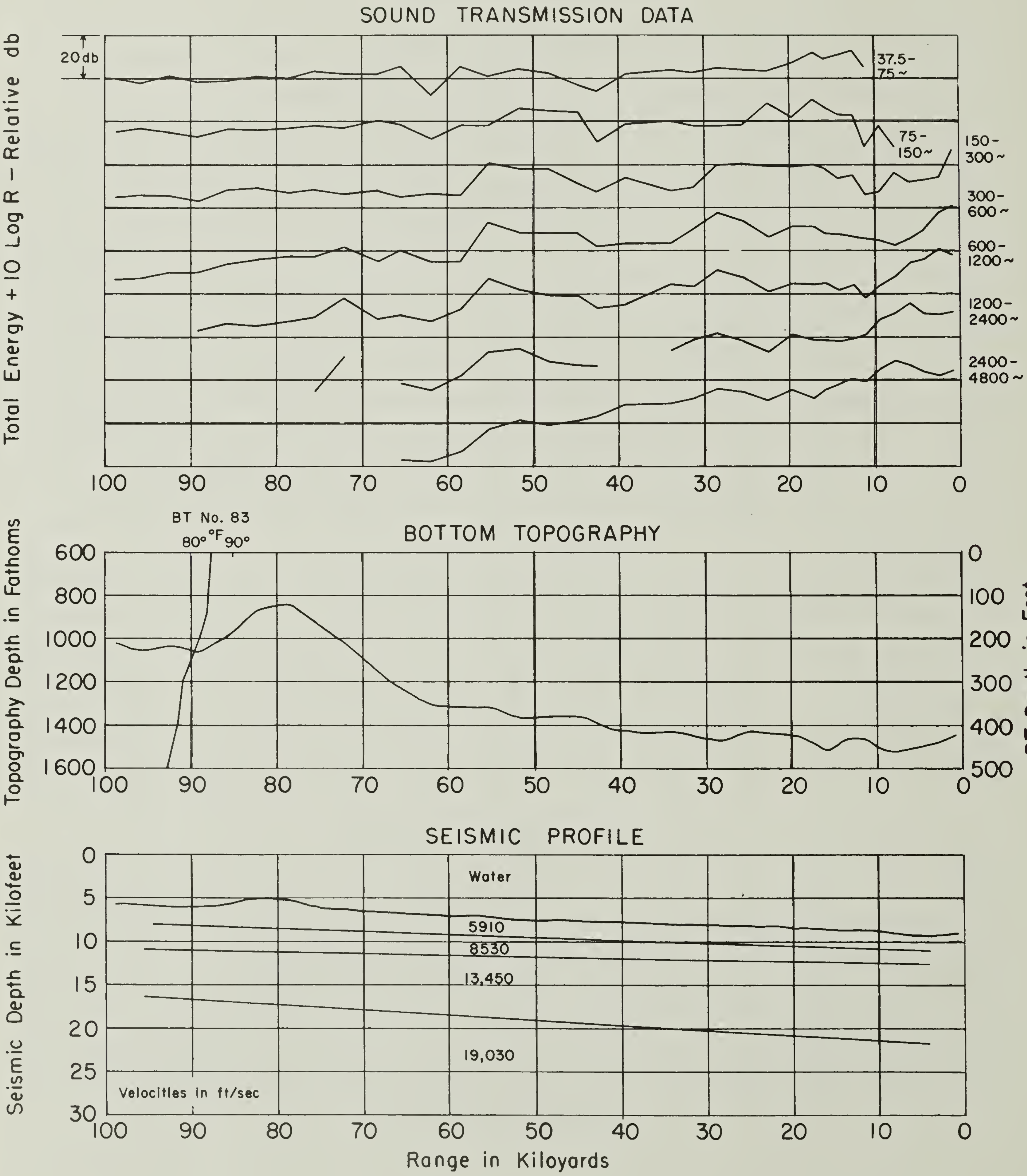
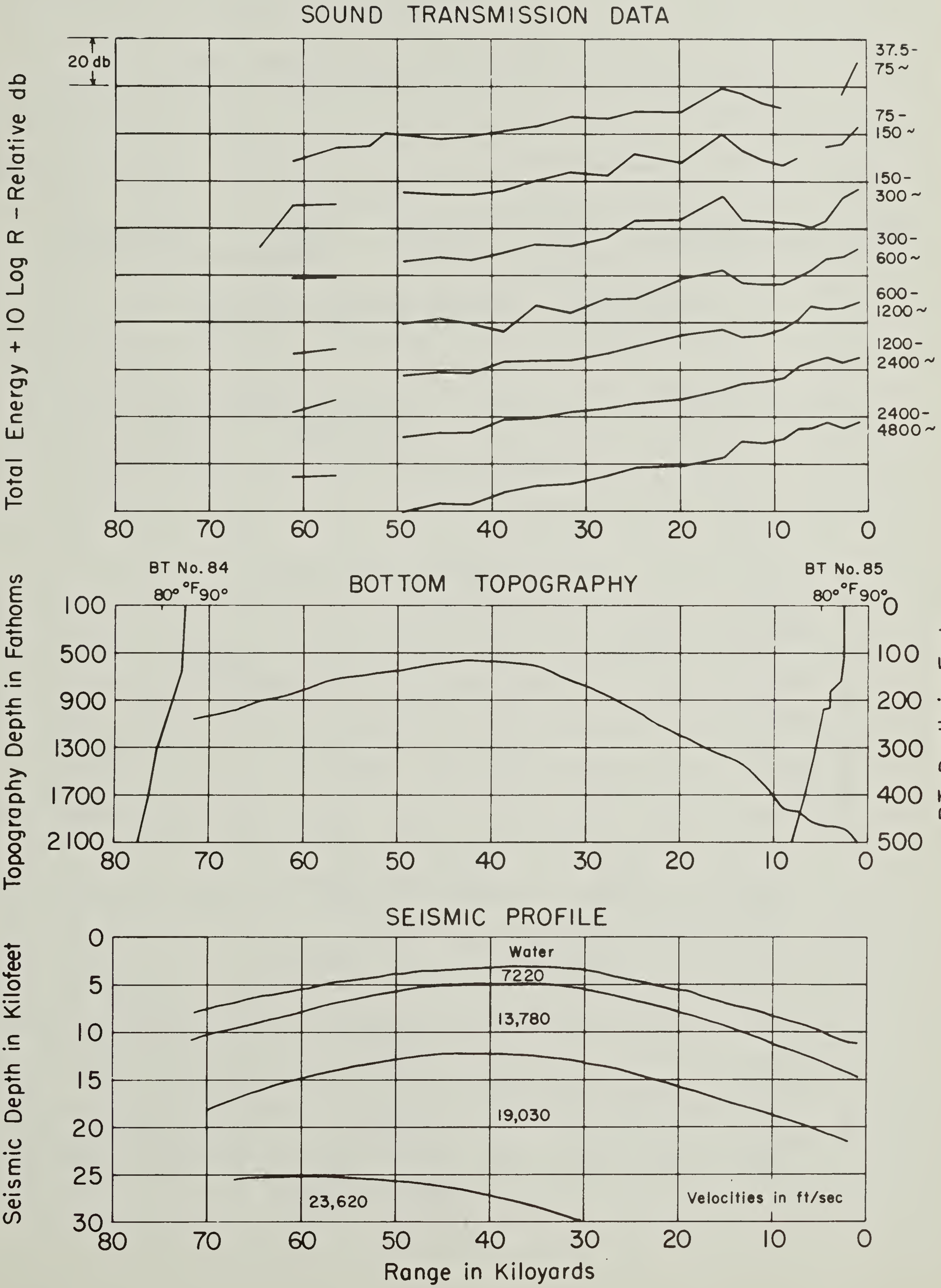
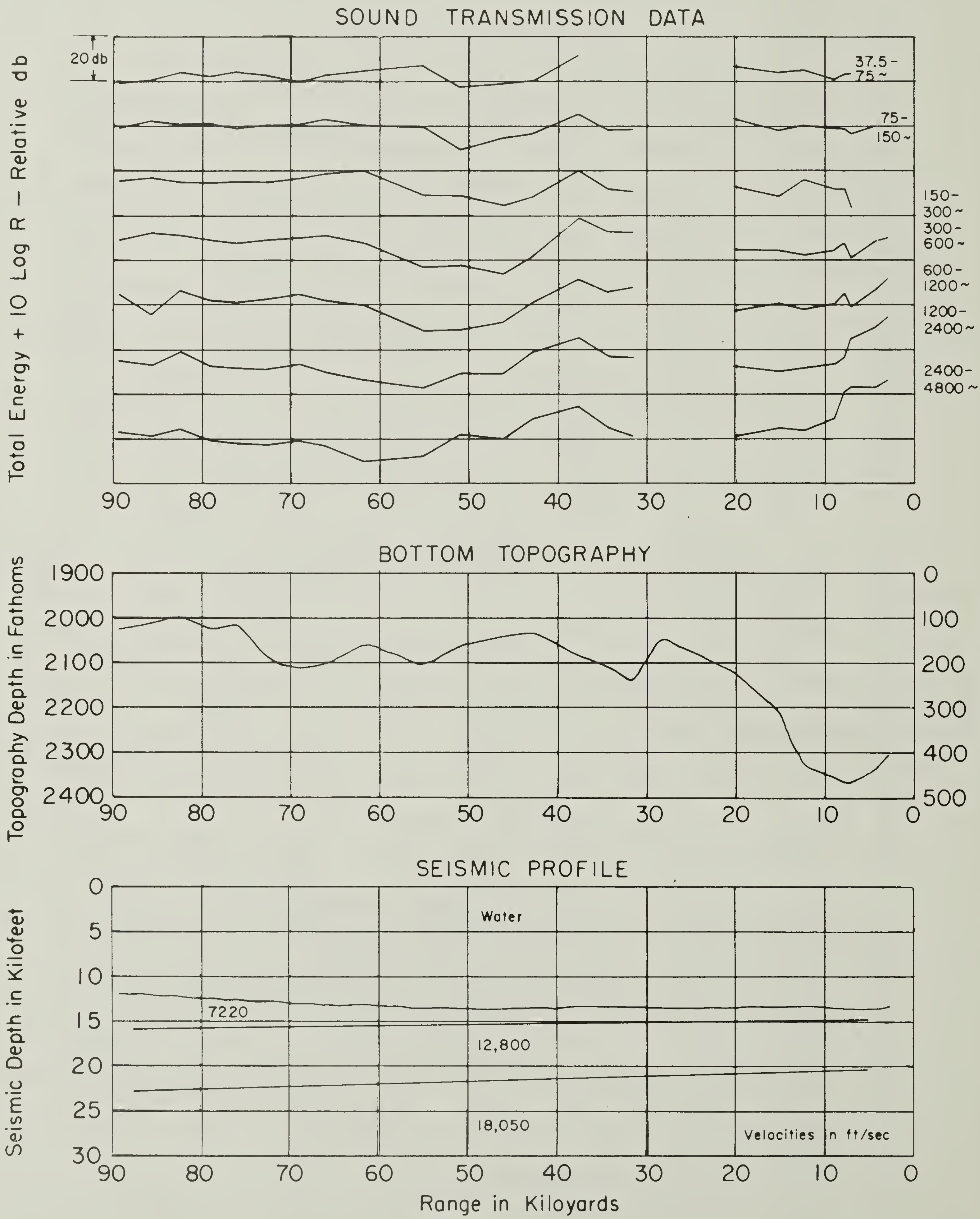


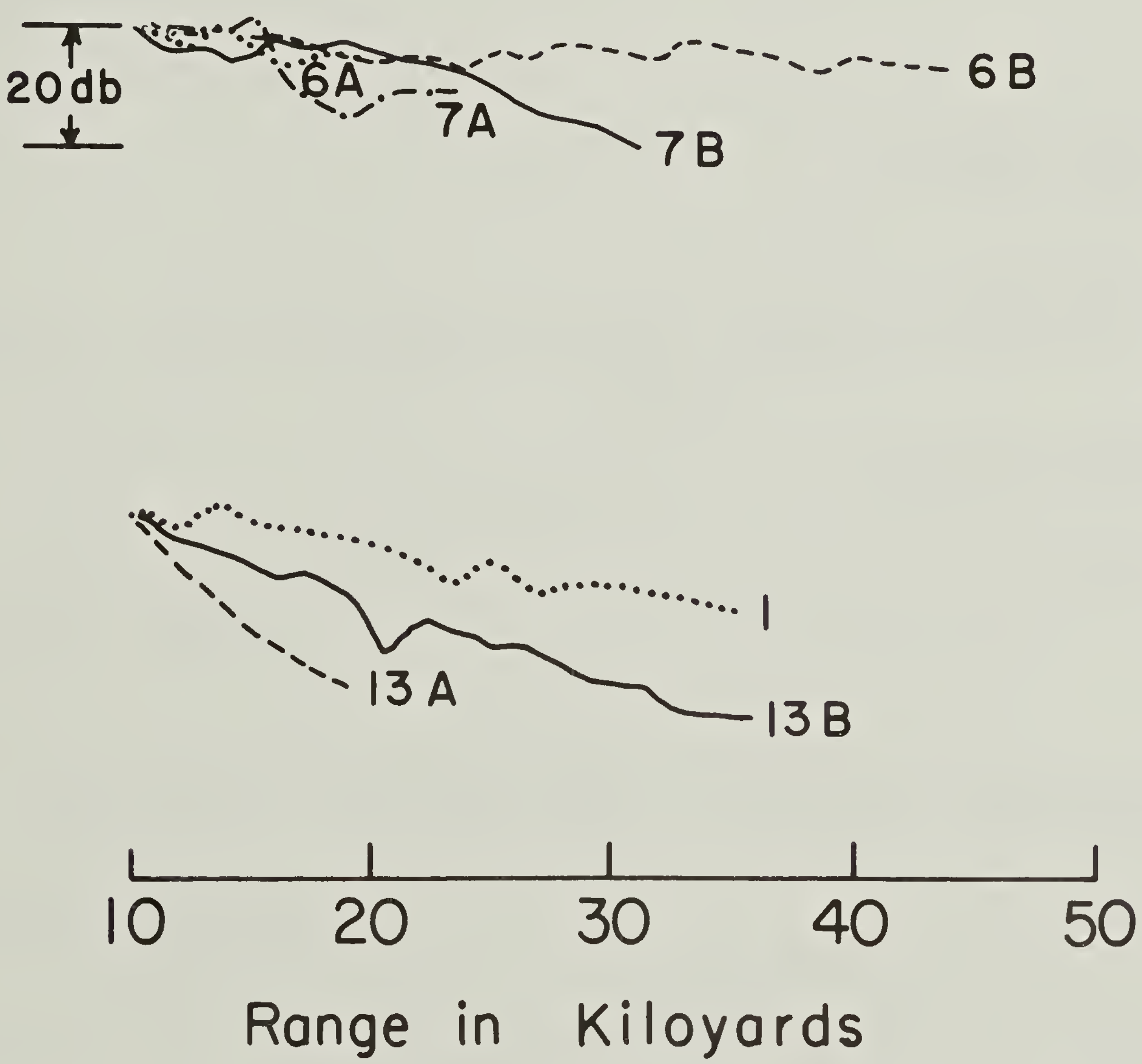
STATION NO. 34



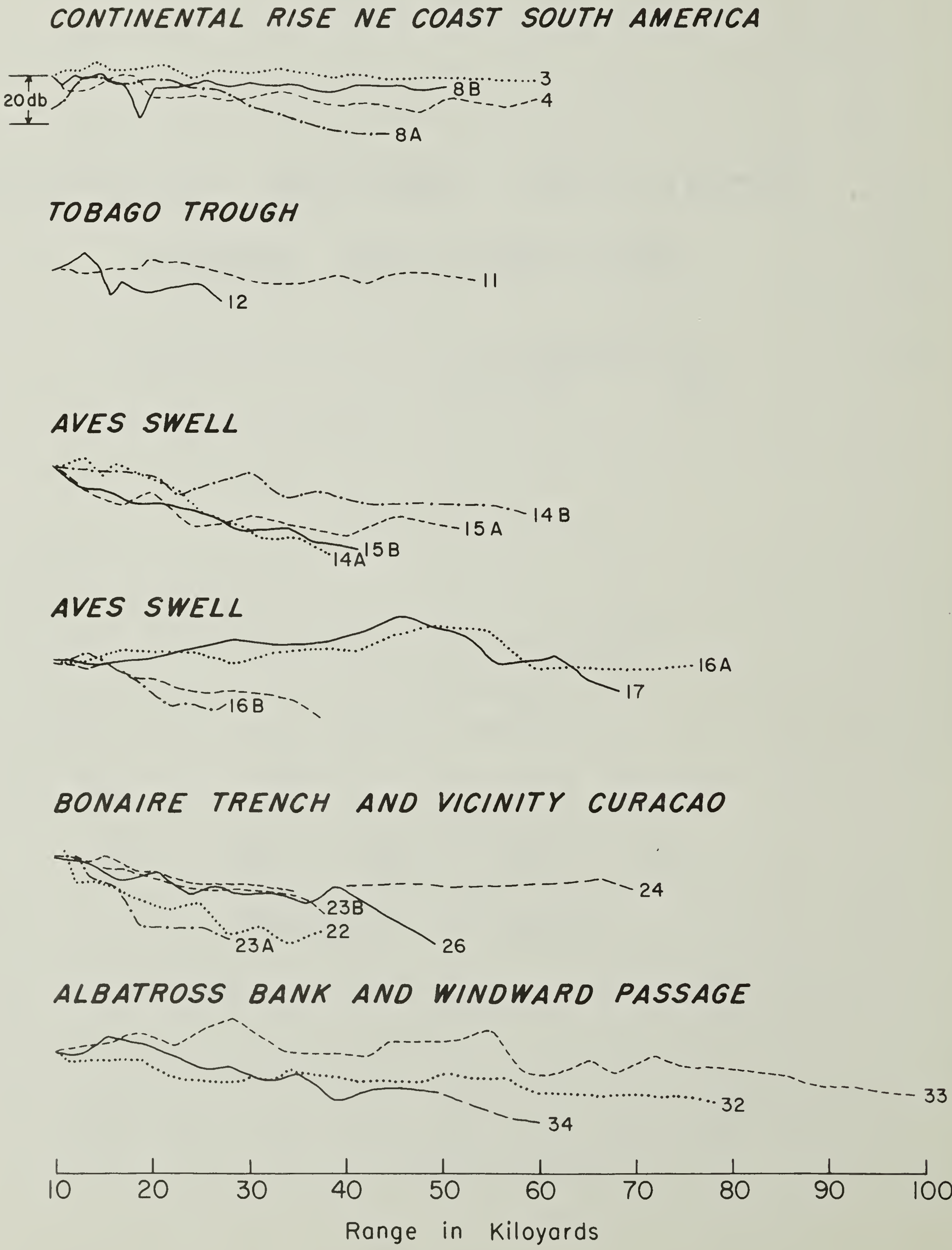
STATION NO. 35



SHALLOW WATER STATIONS
300-600 cps Band



MID-DEPTH WATER STATIONS
300-600 cps Band



DEEP WATER STATIONS
300-600 cps Band